December, 1946
Volume 50, No. 6

Metal Progress

Ernest E. Thum, Editor

Published monthly and copyrighted, 1946, by AMERICAN SOCIETY FOR METALS, 7301 Euclid Ave., Cleveland, Ohio. Subscriptions $5 a year in U.S. and Canada (foreign, $7.50); current copies $1; special reference issues $2. Entered as second-class matter, Feb. 7, 1921, at the post office at Cleveland, under the Act of March 3, 1879. The AMERICAN SOCIETY FOR METALS is not responsible for statements or opinions printed in this publication.

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RYERSON STEEL

Metal Progress; Page 1190

Effect of Changes in Carbides on the Properties of Steel*

By J. B. Austin

Director of Research
Research Laboratory, U. S. Steel Corp.
Kearny, N. J.

CHEMISTS, as long ago as Prof. Campbell's era, could not account for the observed phenomena of solution of carbides of iron if so simple a formula as Fe_3C was employed, yet this has become too generally accepted by metallurgists today. The lecturer advanced the proposition that this compound was similar to wüstite (FeO) or pyrrhotite (FeS); it is known that in these the oxygen (or sulphur) is variable but always more than indicated by the formula. He then reviewed what is known about the structure of chemical compounds and the interatomic bonds or valence to learn what may reasonably be expected as to the composition of austenite and cementite.

The crystalline architecture of cementite is complex, but valency consideration "leads to the relatively simple picture of a structure comprising essentially a framework of close-packed iron atoms held together by metallic bonds, the smaller carbon atoms being held in the interstices by another type of bonding. There is thus a considerable resemblance to the structure of ferrite and of austenite which suggests that although cementite is normally considered a chemical compound, it possesses, in fact, many characteristics of a solid solution. Indeed, cementite appears to be an excellent illustration of the lack of sharp distinction between a solid solution and a compound, though it might be expected to have properties which are in the main those of a compound."

On this basis one would expect that the carbon content might vary in the following ways: *(a)* Minor departure from the stoichiometric ratio is most likely, *(b)* that it may take the form of deficiency of carbon, and *(c)* that composition may vary with temperature.

Considering cementite as a compound only of two elements, iron and carbon, the lecturer — after summarizing the chemical and X-ray evidence — said:

"To sum up, there is ample reason to believe that the carbon content of cementite in equilibrium with ferrite is sensibly constant at the stoichiometric ratio, whereas that of cementite in equilibrium with austenite decreases with increasing temperature. The magnitude of this variation cannot be regarded as precisely determined, but must be relatively small."

It is of course possible that some of the carbon in Fe_3C could be replaced by another element. Theoretically, the element most likely is nitrogen. "Such replacement is difficult to establish beyond question." A study, by the lecturer's colleague L. S. Darken, on carbonyl iron after heating in ammonia at various temperatures and concentrations, indicates that this replacement is possible.

However, the largest chance of variation is by replacement of iron by other metallic elements, similar chemically and within 15% of its size. Much direct and indirect evidence is available on this, and "confirm predictions made on the basis of the structure of cementite — more specifically that, as equilibrium is approached, iron in cementite is replaced extensively by manganese and chromium for which the size factor is most favorable; to a more limited extent by molybdenum and tungsten, for which the size factor is less favorable; and finally to only negligible extent by vanadium for which the size factor is least favorable. Moreover, for a given temperature and carbon content, the alloying element in the carbide

*A summary of the earlier sections, and verbatim quotations from last portion, of the 1946 Edward DeMille Campbell Memorial Lecture, delivered at the annual convention in Atlantic City, Nov. 21, 1946. Full text and complete illustrations will appear in the next volume of *Transactions*.

1*a* — Initial Quenched Structure 1*b* — Reheated 4 Hr. 1*c* — Reheated 24 Hr. at 1700° F. 1*d* — Reheated 72 Hr.

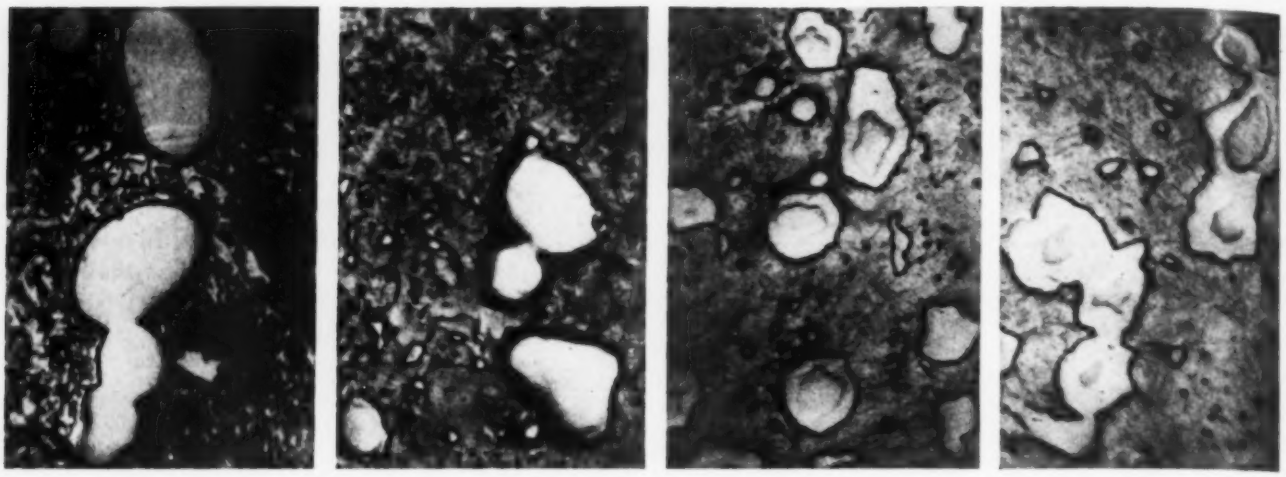

Fig. 1 — Development of Cored Carbides in Iron Alloy Containing 6.0% Molybdenum and 1.3% Carbon on Quenching From 2040° F., Then Reheating at 1700° F. for Various Times. Picral etch, 2000×. (Photographs by R. F. Campbell)

increases linearly with the gross content of the element in the steel, and the partition coefficient is such that at equilibrium the alloying element tends to concentrate in the carbide."

Having reviewed the evidence as to what may be expected under equilibrium conditions, the lecturer then took up the very important implications applying to heat treating processes where equilibrium is not even approached.

"The simplest type of such a process is equilibrating by annealing or tempering, at a given temperature, carbides formed at another temperature at which they may or may not have been in equilibrium. In general, if the temperature of annealing is higher than that of formation, the carbides tend to become enriched in alloying elements, whereas if it is lower, there is a tendency toward impoverishment."

Such variations are large enough to be unmistakably proven by separation and chemical analysis of carbides. Some recorded observations are:

Steel	Treatment	Separated Carbide
2¼% Mn	Tempered 750° F.	4.6% Mn
	Tempered 1250° F.	17% Mn
3¼% Cr	Tempered 850° F.	6% Cr
	Tempered 1025° F.	14% Cr
	Tempered 1200° F.	25.7% Cr

"An example of the reverse change, and a good illustration of the mode of formation of cored carbides, is presented in Fig. 1, which shows the progressive change in an iron-molybdenum-carbon alloy which had been treated initially to produce a complex molybdenum-rich carbide, then subsequently held at a lower temperature, at which a carbide richer in iron, probably cementite, is more stable. This alloy, which contained about 6% molybdenum and 1.3% carbon, was first heated in an evacuated silica tube at 2040° F. for 72 hr., then quenched to produce the relatively massive and hard molybdenum-rich carbide shown in Fig. 1*a*. Samples of the alloy in this condition were then annealed, likewise in a silica tube, at 1700° F. for 4, 24 or 72 hr., which yielded respectively the structures shown in Fig. 1*b*, 1*c* and 1*d*. After 4 hr., there is just visible a thin envelope of softer iron-rich carbide, which after 24 hr. has grown markedly, and after 72 hr. has nearly absorbed the molybdenum-rich core. On subsequent heating at higher temperature the envelope material tends to dissolve, leaving the core intact."

The evidence concerning influence of variable carbides on isothermal transformation is scanty, but revealing. Studies on manganese and chromium steels show that cementite formed in the pearlite region (above the "nose") is alloy-rich, whereas that formed in the bainite region is alloy-poor. Analogous data have been reported by F. E. Bowman and his colleagues for molybdenum steels. Other points brought out by them are:

"1. In alloys with eutectoid carbon content, the segregation of molybdenum in the carbides is much greater at the completion of isothermal transformation, in no case more than 30 min., than in the same alloy quenched and tempered for as long as 250 hr. at the same temperature;

"2. Orthorhombic cementite probably forms exclusively in alloys containing up to 1% molybdenum at 1000° F.;

"3. In alloys containing more than 0.50% molybdenum, transformed isothermally at 1200 or 1300° F., cementite is replaced by the face-centered cubic $(Fe,Mo)_{23}C_6$;

"4. In hypoeutectoid alloys, the molybdenum concentration in cementite formed by tempering

Fig. 2 — Comparison of the Same Field of the Steel Shown in Fig. 1d. Left is after picral etch; right is after the picral etch plus an electrolytic etch in alkaline chromate solution

martensite can be increased to a level greater than that which results in the presence of $(Fe,Mo)_{23}C_6$, after isothermal transformation of austenite.

"All these results are, in general, what one would expect in view of the increasing mobility and solubility of alloying elements with increasing temperature."*

On the basis of the foregoing, one naturally inquires as to the significance of variation in composition of carbides on the behavior of steel.

Perhaps the most significant changes in the carbides themselves are in their hardness (Fig. 2*a*) and their resistance to etching (Fig. 2*b*). Diamond pyramid indentations made under a 2-g. load on the envelope and core of carbides in the molybdenum steel show a difference of the order of 200 d.h.p. numbers. Difference in resistance to etching is illustrated by comparing Fig. 2*a* and 2*b*. Picral attacks the matrix rapidly, the envelopes of the carbides less rapidly and the cores least rapidly, to yield three distinct levels. A subsequent electrolytic etch in alkaline chromate solution dissolves the core but leaves the envelope substantially unaltered, as is evident from the slight change in size of the diamond impressions.

Other properties which may be significantly altered are density, as indicated by change in lattice parameter, and magnetic susceptibility — influenced by the iron content . . . . .

The properties of the matrix change as it becomes depleted or enriched by giving to or receiving from the carbide some of the alloying element which tends to concentrate in that phase. Thus, linear thermal expansion is significantly influenced; electric resistivity is especially sensitive to change in composition of the matrix. It is interesting to note that from a study of the resistance of chromium steels, LeChatelier predicted as long ago as 1898 that chromium concentrates in the carbides.

Other properties of the matrix which may be significantly altered are hardness, magnetic quality, density, lattice parameter, and corrosion resistance, of which the appearance of intergranular attack in high-chromium alloys is an example.

A number of properties of steel (matrix plus carbides) may be influenced by segregation of alloying elements in carbide phases. Some of those, such as secondary hardness, have been discussed in detail by E. C. Bain in his book on "The Functions of Alloying Elements in Steel". There are others which should be mentioned.

The first is resistance to creep at elevated temperature. It is reasonably certain that creep strength is improved by precipitation of fine particles throughout the steel, though it has not been established that the particles need be carbides. The size and degree of dispersion of such particles may well be more significant than their composition, but one cannot ignore the possibility that transfer of alloying element from matrix to carbide on holding at temperature may also be a factor.

A second is tendency to graphitize. In principle, one would expect that replacement of iron in cementite by a stronger carbide-former such as chromium or molybdenum should stabilize cementite and so lessen the tendency to form graphite; conversely, that replacement by a weaker carbide-former might enhance this tendency. The experimental evidence is difficult to interpret, in part because graphitization is influenced by many other factors and in part because of the difficulty of distinguishing between true change in equilibrium and decrease in rate of reaction. Chromium appears to stabilize cementite since, so far as I am aware, formation of graphite has never been observed in steels containing about 2% chromium. There is likewise some evidence that molybdenum is effective in preventing graphitization, yet there are well-authenticated instances of graphitization in molybdenum steels. On the other hand, it is possible that the enhanced tendency to graphitize observed in many aluminum-killed steels may be due in part to a decrease in stability of cementite resulting from the presence of aluminum.

*From this point on the wording is that of the lecturer although, in the interests of readability, the many elisions are not noted.

Another example is the effect of carbide composition on susceptibility of steels to attack by hydrogen at high temperature and pressure. In the synthesis of ammonia and of certain hydrocarbons, steel is often damaged by decarburization, and by the appearance of cracks which are commonly ascribed to the formation of methane at high virtual pressure through reaction of carbide with hydrogen diffusing into the metal. Presence of alloying element in the steel, or more specifically in the carbide, appears to stabilize the carbide with consequent alleviation of the attack. Presence of silicon, nickel or copper, all noncarbide formers, has virtually no effect. Manganese has a significant influence, with chromium, tungsten and molybdenum increasingly effective. All of these elements concentrate in the cementite, or form higher carbides, and so become more effective as they are present in increasing concentration. Columbium, zirconium, vanadium and titanium are the most effective elements, conferring immunity to a very high temperature even when present in small concentration, because they hold the carbon as a very stable carbide.

This behavior is significant in the welding of steel which is to resist attack by hydrogen. The welding rod is usually a high alloy material, and so commonly transforms during cooling in the bainite or martensite ranges, hence, forms carbide relatively lean in alloying elements. Unless this carbide is subsequently annealed to enrich it in alloying elements, the steel is susceptible to attack by hydrogen.

The foregoing examples illustrate how misleading the usual chemical analysis of a steel may be, for, in many instances, the significant fact is the distribution of an alloying element between matrix and carbide and not the total amount in both phases.

It is appropriate now to review what we have learned about carbides to see how it bears on other principles, as, for instance, the influence of alloying elements on the rate of isothermal transformation to pearlite — that is, transformation nucleated by carbide — in eutectoid steels.

In eutectoid carbon steel, as the temperature of transformation decreases the rate of nucleation increases, as is common in many undercooled systems; this tends to increase the rate of transformation.* At the same time, the diffusivity of carbon decreases, which, if the carbon gradients remain unchanged, tends to retard transformation. Yet Robert F. Mehl has shown that the rate of growth of pearlite nuclei *increases* with decreasing temperature, which indicates that the carbon gradients change in such a way as to increase the net rate of diffusion of carbon.

Addition of a noncarbide forming element, such as nickel, silicon or copper, can influence transformation in two ways, either of which would tend to lessen its rate:

First, it may decrease the rate of the gamma to alpha transformation of iron. Nickel is especially effective in retarding this transformation even in the absence of carbon.

Second, it may decrease the rate of nucleation of carbide. Thus, an element which tends to decrease the stability of cementite might decrease the probability of forming a carbide nucleus and thus lessen the net transformation rate.

Experimental data, at least those

*The lecturer here used a lantern slide showing the well-known S curve for eutectoid steel (*Metal Progress* Data Sheet No. 38, 1946 edition).

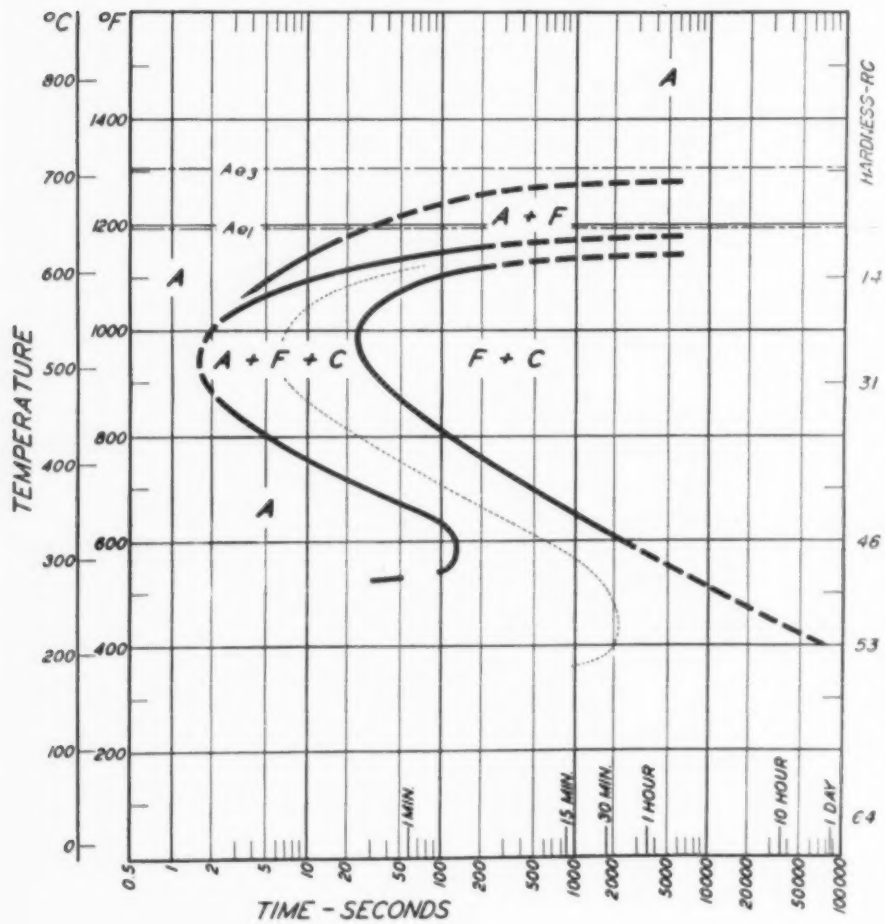

Fig. 3 — Isothermal Transformation Diagram of Fine-Grained Steel Containing 3.88% Nickel, 0.33% Manganese and 0.55% Carbon. Austenitized at 1480° F. Curves for beginning and end of transformation are of the same shape as for a plain carbon eutectoid steel, but are shifted to right and lowered slightly. Minimum times ("nose" of curves) are at 1050° F., nucleating after 1 sec. and complete after 5 sec. for the eutectoid steel, whereas for the nickel steel the nose temperature is 975° F. and the respective times 1.5 and 22 sec.

now available, show that, in general, these elements shift the isothermal transformation curve slightly in the direction of longer time without essentially altering its shape, as is illustrated by the diagram for a 4% nickel alloy, presented in Fig. 3. This suggests that the effect of such alloying elements is chiefly to slow up the gamma→alpha transformation in the pearlite region.

Carbide forming elements may have a similar influence, since manganese and chromium are likewise effective in retarding the rate of transformation of iron, but one would also expect, since they tend to concentrate in cementite, that they would directly affect the rate of carbide formation.

For instance, since manganese tends to segregate in cementite to form a continuous series of solid solutions ranging from Fe_3C to Mn_3C, the necessity for diffusion of manganese, which diffuses much less rapidly than carbon, might contribute to retarding the transformation. Moreover, the decrease in diffusivity of manganese and of carbon with decreasing temperature would seem to favor the appearance of a maximum rate in the pearlite region, unless the concentration gradients change (as they appear to do in carbon steels). That there may be a definite, unmistakable maximum rate of transformation to pearlite in manganese steels is, however, amply demonstrated by some of the diagrams presented at this meeting by Axel Hultgren, a good example being his diagram for steel containing 2.90% manganese and 0.77% carbon which is reproduced in Fig. 4.

The influence of stronger carbide formers, such as chromium, molybdenum, tungsten and vanadium, is less simple because of the tendency to form complex carbides, especially at temperatures approaching Ae_1. Thus one must take into account not only the effect of such elements on the rate of gamma→alpha transformation and the necessity for their diffusion into the carbide, but also the greater difficulty of forming a more complex nucleus. As an illustration, the unit cell of cementite contains but 16 atoms whereas that of $(Fe,Mo)_{23}C_6$ contains 116. It is only reasonable, therefore, to expect that the probability of forming such a nucleus (hence, the rate of nucleation) should be markedly less than in a plain carbon steel. Combination of these three factors, all of which operate in the same direction, provides a possible explanation of the fact that the isothermal transformation curves for steels containing these elements commonly show a maximum rate of transformation within the pearlite region and that this region covers a narrower range of temperature than is found in carbon steels. It would appear that in such steels the low diffusivity of the alloying elements, together with the difficulty of forming a complex nucleus, more than offset the influence of a change in concentration gradients.

On the basis of the foregoing speculations, it is possible to explain why these elements have relatively little effect on the position of the bainite portion of the isothermal transformation curve, since, in this range, the carbide formed is commonly alloy-lean cementite which differs but little from that formed in carbon steels.

In conclusion, it is now possible to answer, at least in part, the questions with which this discussion began. The composition of cementite appears to vary measurably in several different ways. When in equilibrium with austenite its carbon content may be significantly less than that corresponding to the formula Fe_3C, the deficiency increasing with increasing temperature. It is possible that carbon may be replaced to a limited extent by nitrogen. Iron atoms can be replaced by atoms of other carbide forming elements which can fit into the cementite structure -- more specifically, by atoms of manganese, chromium, molybdenum, tungsten, or vanadium. At equilibrium, on annealing, or on isothermal transformation in the pearlite region, these elements tend to concentrate in the carbide phase, depleting the matrix and altering many of the properties of the steel.

These answers are admittedly neither final nor complete. Moreover, they raise, in turn, a number of other questions; indeed, I have in this lecture raised more questions than I have settled. But these new questions serve to emphasize gaps in our knowledge and will, I hope, stimulate investigation in this fruitful field in which Professor Campbell was so notable a pioneer.

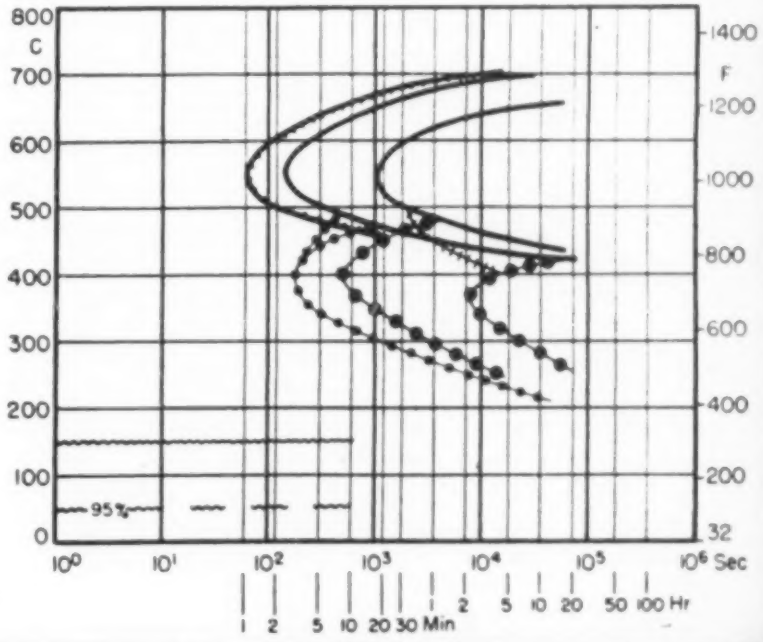

Fig. 4 — Isothermal Transformation Diagram of Alloy Steel Containing 2.90% Manganese and 0.77% Carbon, Austenitized at 2375° F., Showing Higher Rate of Transformation to Pearlite Than to Bainite (After Hultgren)

A Fantasy

By Cy Anide
Filac, Usonia

The Mystery of the Metal Congress

SLOWLY and stealthily the Figure crept up the stairs. Its approach had been so quiet that Fred Queary, plodding up the steps, might not have seen it, had it not brushed against a man right ahead of him. Fred was a reporter, and reporters are supposed to be hardy souls, yet the unrealistic Form sent a shiver through him. Then Fred received a second shock. Although pushed to one side by the Thing, the man ahead gave no sign that he saw who did it!

Fred stopped and collected his thoughts. A week ago, when he had been assigned to cover the National Metal Congress for the Filac *Blowhole*, he had been bitter. Why should a layman like himself try to get news out of a technical convention that was to be covered by top-notch technical writers? Even an hour ago, as he tried to brighten the prospects at a nearby tavern, the best he had been able to hope for was a glow, so he wouldn't mind too much if he did learn something in the endless exhibits. But this Apparition, or whatever it was, this Apparition! — he might get a story yet.

He hurried on into the Auditorium and looked around quickly to see what had become of It. Hundreds of men and women moved from one exhibit to another. Here and there pairs or groups were earnestly discussing points of interest as they examined the displays. Only a few feet away two men were arguing:

"Maybe so, but for toughness I say . . . ." His sentence was suddenly interrupted. Fred turned just in time to see him floored, evidently by a blow from a grotesque Figure who had appeared without warning. It wasn't *The* Figure, however, but a rough fellow who looked like an ex-heavyweight. Instead of causing an alarm, the blow seemed to draw no one's interest beyond a casual glance, and the man who had been hit got up and went on with his argument.

"Queer fish, these Metallurgists", muttered Fred and took up again his search for the Figure on the stairs. During the next hour his efforts yielded nothing except contacts with some incidents so strange that he sought out a bar to try to figure it all out. He was happy to see among the patrons the man who had been knocked down earlier in the day. Since he was in company with a bright looking girl, Fred decided he really must join them, his hopes of a story very high indeed.

"How do you like the Show?" asked Fred after he had gotten around to introduce himself and had found his companions were Ann Ealing and Norm A. Lyse, chief metallurgist of a company whose name he did not recognize.

"Fine Show, same as usual," answered Norm,

Floored by a Grotesque Figure

while Ann insisted it was even better than ever.

"Do you always have fights at these things?"

"What fights?" said Norm, bristling.

"I mean these queer guys going around knocking things over," countered Fred.

"Oh them, sure. You aren't a metallurgist, I can see."

"Now, Mr. Lyse, what is the idea of that little fellow in a red suit that tears about pushing people? I saw him go right between two friends shaking hands. Why don't they tie him down or kick him out? Who is he?"

"He's Well D. Bility. He comes every year. He is somewhat of a mystery. We'd all like to put him to work in our plants, but so far he just pushes us around and causes arguments, so we mostly ignore him."

Fred was puzzled; it seemed a little vague. He tried a different lead. "Now that angular person, you probably saw him. Everyone in the National Silumin booth ducked when he came there, yet I saw two other exhibits push him out. In most of the places where he went the people didn't seem to know he existed. Do you know the guy I mean?"

Norm sipped his drink as he pondered. "Probably it's Notch Sensitivity, from your description. We used to think he was a figment of the imagination, like a ghost, but Doc. Hoyt and Doc. Gensamer and Doc. McAdam all proved he was very much alive. So now we have to live with him! The worst of it is, the birds who have gotten the best acquainted with him each has a different name for him, the troublesome . . . ."

A crash at the end of the bar interrupted the sentence. Without waiting his turn a strapping youngster in poorly-fitting evening clothes muscled his way to the bar and upset several people in his eagerness to get service.

"That's Harden A. Bility," said Lyse in a matter of fact tone. "Walter Jominy got him formally introduced here and now we can't hold him down. It's funny, too — he's making a lot of friends even though he does upset some."

"I thought he was supposed to be someone of importance, incognito", volunteered Ann. "He certainly has a definite charm."

Harden A. Bility Muscled His Way Into the Scene

"He has," said her metallurgist friend, "but just how important *is* he, and what others should he replace? I tell you, sometimes I wish I had taken the cloth. We metallurgists have to contend with Grain Growth, Second Hardness, Creep, and De Carb, we have Stress Corrosion and Mike Rowshrinkage and Fat Teague and Austin Ittick. Some, I think, are ghosts, but some are sure real enough. We think they all can be licked and made to work for us. But they have us guessing. Now take Tuff Ness. I think he is best shown up by the notched Charpy. No one can spoil *that* argument."

Whack!

Fred turned to find his friend again flat, the same Fellow standing over him as had hit him earlier.

"I'm Tuff Ness," said the Bruiser, as he went away with Ann on his arm.

"See what I mean?" said Norm, resignedly.

Piercing Mill Making a Seamless Tube of 7% Chromium Steel (Timken Roller Bearing Co.)

Alloy Steels Intermediate in Chromium

By Claude L. Clark

Research Metallurgical Engineer
Steel and Tube Division
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Canton, Ohio

IN THE LAST issue of *Metal Progress*, starting on page 897, was an article entitled "Requirements of Steels for High Temperature Service", which also discussed with some generality the influence of composition, structure, and prior history on the suitability for long service under severe conditions. What follows is really a continuation of the November manuscript, and will attempt to show how the general principles have been successfully applied to alloy steels intermediate between the older chromium steels containing respectively 5 and 12% chromium.

The more common types of intermediate alloy steels now available for high temperature service are as follows:

4 to 6% Chromium Type Steels
- Plus 0.50% Mo (A.I.S.I. Types 501 and 502)
- Plus 0.50% Mo+1.5% Si
- Plus 0.50% Mo+1.0% Si+0.50% Al
- Plus 0.50% Mo+Cb
- Plus 0.50% Mo+Ti
- Plus 1.0% Mo

Chromium Above 6.0%
- 6 to 8% Cr+0.50% Mo+1.0% Si (max.)
- 6 to 8% Cr+1.0% Mo+1.0% Si (max.)
- 8 to 10% Cr+0.50% Mo+1.0% Si (max.)
- 8 to 10% Cr+1.0% Mo+1.0% Si (max.)
- 8 to 10% Cr+1 to 1.5% Mo+0.50% Si (max.)

There is a historical basis for classifying them into two groups, since the 4 to 6% chromium steels were among the first developed for high temperature service and the higher alloyed steels may, in many respects, be considered as modifications of this original grade.

4 to 6% Cr-Mo type steels were originally introduced because of their superior corrosion resistance to plain carbon steel in hot petroleum products. At the time (1927), it was commonly believed that all of the pearlitic type steels possessed the same high temperature load-carrying ability. As mentioned in the introductory paragraphs, the first steel contained no alloying addition other than chromium, but it was soon found that this straight chromium steel was susceptible to "temper embrittlement", in the sense that, after prolonged service at temperatures within the range of about 800 to 1000° F., it lost a considerable part of its room temperature impact resistance. It was found that this could be corrected by adding tungsten or molybdenum, and a very large percentage of this analysis made today, in either its standard or modified form, contains 0.50% molybdenum.

The American Iron and Steel Institute has standardized two types with chemical composition 4.00 to 6.00% Cr, 0.03% max. S, 0.04% max. P, 1.00% max. Si and 1.00% max. Mn. Type 501 has carbon over 0.10%; Type 502 has carbon 0.10% max. Physical properties in the annealed condition, as given in Section 24 of the A.I.S.I. "Steel Products Manual" (May 1946) are as shown in Table III on the next page, and readily achieved mechanical properties in Table IV. Recommended thermal treatments are as follows:

	Type 501	Type 502
Initial forging	2100 to 2200° F.	2100 to 2200° F.
Full annealing:		
Cool slowly from	1525 to 1600° F.	1525 to 1600° F.
Low annealing	1325 to 1375° F.	1325 to 1375° F.
Quenching	1600 to 1700° F.	(Generally used
Tempering	400 to 1400° F.	) as-annealed

More recently — that is, within the last ten years or so — certain other changes have been made in this analysis so as to improve certain of its high temperature characteristics. While the corrosion resistance is ample for the refining of many crude petroleums, its oxidation resistance decreases rapidly at temperatures over 1200° F.

Table III★ — Physical Properties of Types 501 and 502 in the Annealed Condition

Modulus of elasticity in tension	29.0×10^6 psi.
Density, lb. per cu.in.	0.28
Specific electrical resistance at room temperature, microhms per cm. per sq.cm.	40
Specific heat, B.t.u. per lb. per °F. (32 to 212° F.)	0.11
Thermal conductivity, B.t.u. per hr. per sq.ft. per ft. per °F.	
at 212° F.	21.2
at 932° F.	19.5
Mean coefficient of thermal expansion per °F.	
32 to 212° F.	6.2×10^{-6}
32 to 600° F.	6.8×10^{-6}
32 to 1000° F.	7.2×10^{-6}
32 to 1200° F.	7.3×10^{-6}
Melting point range	2700 to 2800° F.
Magnetic in all conditions	

Referring to our previous discussion it is evident that this oxidation resistance can be improved by the addition of either silicon and aluminum or both. Consequently modifications were developed containing up to 1.5% silicon, and also 1.0% silicon plus 0.50% aluminum. Since aluminum is a powerful ferrite former it is evident that the amount of this element must be limited if a two-phased structure is to be avoided. The beneficial effect of this increased silicon content on the oxidation resistance has been previously shown in Fig. 7.

This effect is shown somewhat differently in Fig. 10. With silicon at 1.0 to 1.5% this steel has a high resistance to oxidation in air up to and including 1500° F. Without this, resistance decreases rapidly at temperatures over 1200° F. The addition of 0.50% aluminum to a 1.0% silicon steel has the same influence at temperatures up to 1500° F. as a further increase in silicon to 1.50%, but at the higher temperatures the combination is more effective than the higher silicon alone. Oxidation resistance of all of these steels, however, breaks down over 1500° F. Service data from certain refineries also show that the increased silicon and the aluminum addition improve the resistance to hot petroleum products.

A characteristic of the 4 to 6% Cr-Mo steel and of the modifications mentioned, which is detrimental for certain types of applications, is its pronounced susceptibility to air hardening. Depending on the chromium and carbon content, hot rolled bars of this steel may possess a Brinell hardness of the order of 400. Likewise in annealing, the cooling rate must be slow and carefully controlled or the resulting hardness will be greater than desired. This hardness, of course, results from the dispersion of carbides in a finely divided form throughout the matrix, thus producing a martensitic structure (Fig. 2, page 900, November issue).

There are two possible procedures for eliminating this. One consists of so adjusting the analysis that only a relatively small amount of the steel undergoes the gamma-to-alpha transformation on cooling. This results in a two-phased steel (Fig. 4, page 900, November issue).

The other method consists in removing carbon from the field of reaction. Theoretically this could be accomplished by having carbon-free steel but this is not only impossible to produce on a commercial scale but would also adversely affect the mechanical properties. This same result could be accomplished by the addition of elements which not only have a very high affinity for carbon but also whose carbides are highly insoluble at the temperatures used for heat treatment. Both columbium and titanium fulfill these requirements, and their addition therefore has the same influence, insofar as hardening is concerned, as decreasing the carbon content.

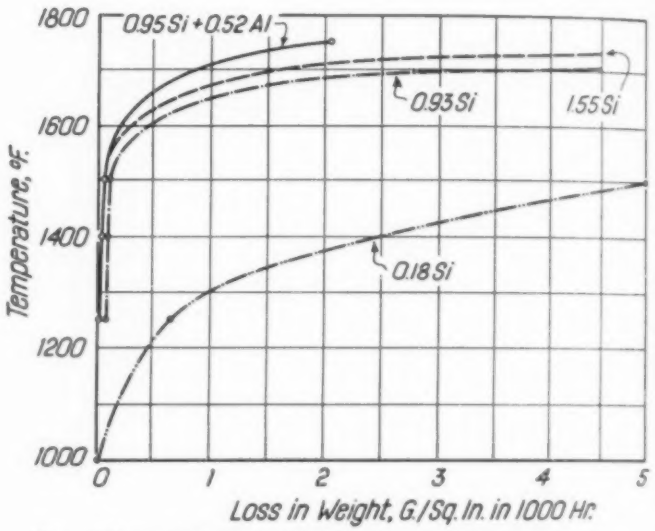


Fig. 10★ — Influence of Silicon and Aluminum on the Oxidation Resistance in Air of Types 501 and 502

For the complete elimination of air hardening characteristics it is often recommended that the columbium content be seven to nine times the carbon content and the titanium content be five to seven times the carbon content. Both of these elements are, however, ferrite formers, and in order to prevent the appearance of appreciable amounts of free ferrite in a duplex microstructure it may be necessary — especially when relatively large amounts of additional ferrite formers are

★Tables and figures are numbered consecutively with article in last month's *Metal Progress*.

present — to use somewhat lower amounts. Some air hardening ability will remain, but the analyses can be so adjusted that the maximum Brinell will not exceed 200.

It is claimed that the addition of either of these elements will increase the surface stability since, through their addition, the chromium which would ordinarily be combined with the carbon is released for solution. While this would have a beneficial influence, the degree of improvement would be of a relatively low order of magnitude. It may be, of course, that these elements exert a more appreciable influence on the type of protective layer produced.

Columbium is also said to increase the creep resistance, and Fig. 11, by the Electro Metallurgical Co., is advanced as proof. The columbium-bearing steels were, however, tested in the hot rolled and tempered (1380° F.) condition while the simple steel was in the annealed state. Heat treatment, and thus the structural characteristics, may account for a portion of this difference. In

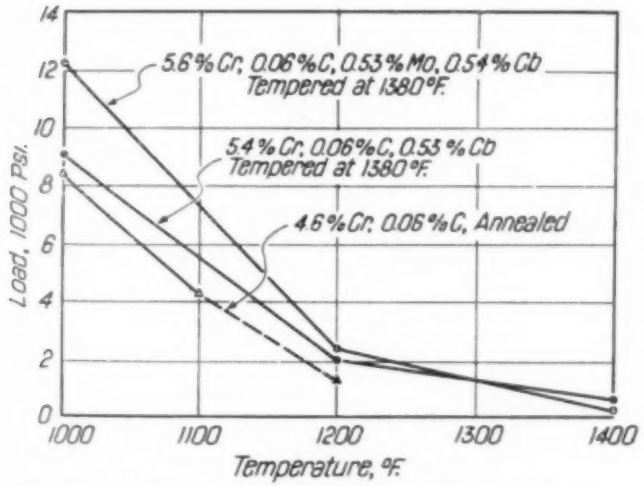


Fig. 11 — Creep Strengths (1% in 10,000 Hr.) of Low Carbon 5% Chromium Steel With Columbium and Molybdenum Additions (Electro Metallurgical Co.)

fact our own results at Timken Roller Bearing Co. indicate the differences to be slight when all of the steels are in the annealed state. Even so, however, the addition of columbium or titanium would be beneficial, for through their addition the normalizing and tempering treatment could be more readily applied commercially, and there would be less damage from unwise welding or heating during fabrication or repair.

The rate of deformation used in determining the load-carrying ability may also have an appreciable influence on the test results. The 100,000-hr. rupture strength of certain of the 4 to 6% Cr-Mo

Table IV — Mechanical Properties of 4 to 6% Cr, 0.5% Mo Steel

	Type 501 (C >0.10%)	Type 502 (C <0.10%)
Plate, bars and forgings (annealed)		
Tensile strength	70,000	65,000
Yield at 0.2% offset	30,000	25,000
Elongation in 2 in.	28	30
Reduction of area	65	75
Brinell hardness	160	150
Izod test		85 ft-lb.
Creep strength; load for 1% elongation in 10,000 hr.		
At 900° F.	16,000 psi.	
At 1000° F.	9,000	
At 1100° F.	5,000	
At 1200° F.	2,000	
At 1300° F.	1,500	

Type 501 Bars, Oil Quenched From 1650° F.

	Tempered 1000° F.	Tempered 1100° F.	Tempered 1200° F.
Tensile strength	175,000	140,000	115,000
Yield at 0.2% offset	135,000	110,000	90,000
Elongation in 2 in.	15	18	20
Reduction of area	50	55	60
Brinell hardness	370	290	240

modifications are shown in Fig. 12. All of these steels were annealed from 1550° F., and it will be observed that at temperatures of 1100 to 1300° F., inclusive, the titanium modification possesses the lowest rupture strength. At the lower temperatures (that is, 1000 and 1100° F.), the standard 4 to 6% Cr-Mo steel has the highest strength, while at the more elevated temperatures the silicon modification is the outstanding one due to its greater surface stability.

These values were determined under slightly oxidizing conditions. If the atmosphere had been more highly oxidizing or if it had been corrosive, certain of the modifications might have showed to even greater advantage.

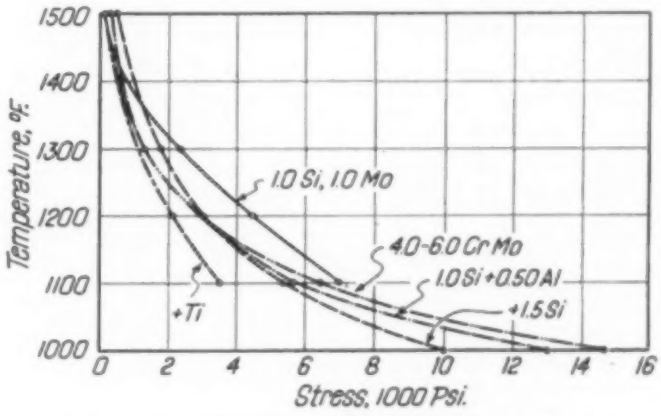


Fig. 12 — Rupture Strength at 100,000 Hr. of 4 to 6% Cr-Mo Steel and Several Modifications

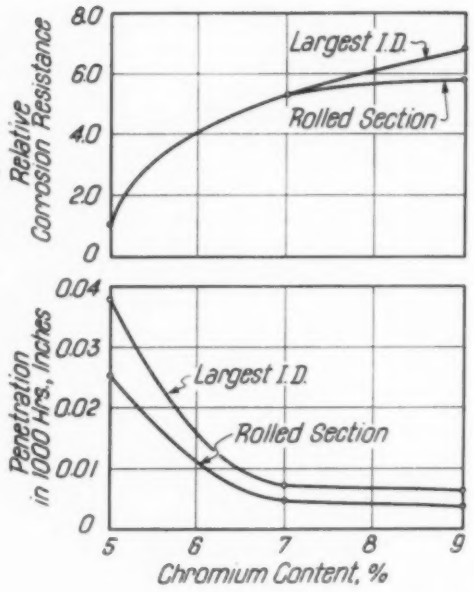


Fig. 13 — Comparative Corrosion Resistance of 5%, 7% and 9% Chromium Type Steels

Chromium Over 6.0% — As previously indicated these steels may be considered as modifications of Types 501 and 502, their main difference being the increased chromium. The effect of the same additional alloying elements would, in general, be the same as with the steels previously discussed. However, because of the higher chromium, these steels are nearer to the outer boundary of the gamma loop, and consequently they are more readily made two-phased by the addition of the ferritic formers silicon, aluminum and molybdenum. If a single-phase steel is desired, the silicon seldom exceeds 1.0%; likewise (especially in the 9.0% chromium type), the molybdenum content should not exceed about 1.0%. On the other hand, if nonhardenable ferritic (or even partially ferritic) steels are desired, this group affords a convenient basis from which to start.

Increased chromium is primarily for increasing the corrosion resistance, especially in hot petroleum products, rather than the oxidation resistance. Improvements in this latter property can be obtained more economically through the addition of silicon or aluminum to the lower chromium steels. For example, on the basis of 1000-hr. laboratory tests in air, the oxidation resistance of each steel of this group is of the same order of magnitude and also nearly identical to that of the high silicon modification of the 4 to 6% Cr-Mo steel.

Improvement in corrosion resistance as the chromium content is increased above 5% may vary greatly, depending upon the type of crude and the operating conditions. It is definitely known, however, that these higher chromium steels are rendering satisfactory service in applications in which the regular Type 502 was unsatisfactory. As indicated by Fig. 13, results from one refinery indicate that, under their particular conditions, the corrosion resistance of the 7% chromium steel is over five times that of the 5% chromium steel, and that of the 9% chromium steel, about six times. These reports also indicate that the corrosion resistance of the 9.0% chromium type steels is influenced to a greater degree by cold working, such as in expanding into tube return headers.

As in the case of Type 501 and 502, the corrosion resistance of this group of higher chromium steels can be further enhanced by increasing the silicon, or by the addition of aluminum.

Increasing the chromium is not for the purpose of increasing the prolonged high temperature strength. In fact, on the basis of the stress required for a creep rate of 0.10% per 1000 hr., the reverse may be true — as shown in Fig. 14. If the steel contains about 0.50% molybdenum and 1.0% silicon, the creep strength decreases progressively as the chromium content is increased from 5.0 to 7.0 to 9.0%. Molybdenum is beneficial up to 1.0%, although even with this higher content both the 7.0 and 9.0% chromium steels possess creep characteristics very similar to that of Type 501 and 502. In other words, the increased chromium is detrimental insofar as

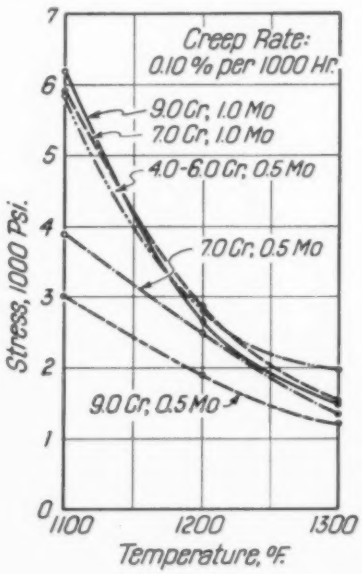
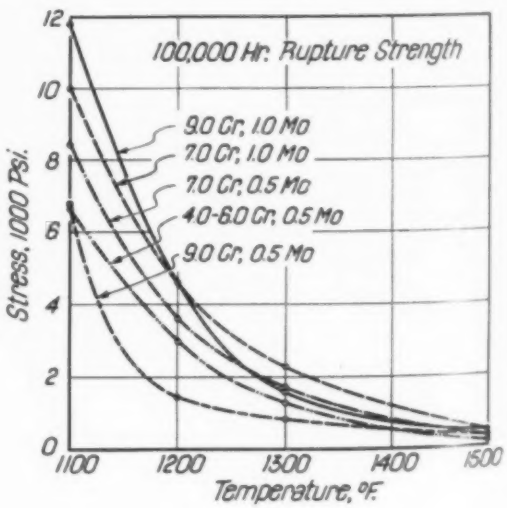


Fig. 14 (Left) — Creep Strength of Higher Chromium Steels Containing 1% Silicon (Max.)

Fig. 15 (Below) — Rupture Strength (100,000 Hr.) of Higher Chromium Steels Containing 1% Silicon (Max.)



the creep strength is concerned, but this can be counterbalanced by an increase in molybdenum.

That deformation rate may be an important factor in the evaluation of the load-carrying ability of these steels is again apparent from the values of Fig. 15. When the 100,000-hr. rupture strength is used as the basis of evaluation, then the strength increases as the chromium goes up to 7.0%, and is further increased by an increase in molybdenum. A further increase to 9.0% Cr lowers the strength below that of 4 to 6% Cr-Mo steel at all temperatures except 1100° F. Increasing the molybdenum in the latter to 1.0% results in a rupture strength superior or equal to that of the 7% Cr, 1.0% Mo steel at 1100 and 1200° F., but at the higher temperatures the strength falls off at a more rapid rate.

It is apparent that broad generalities cannot be drawn with respect to the load-carrying ability of these higher chromium steels; their relative merits depend both on the rate of deformation and the temperature. However, for oil cracking still tube service it is believed that the higher rates of deformation — such as in the stress-rupture test at high loads — should be used in evaluating the load-carrying ability.

Again it must be realized that all of the stress values which have been presented were determined by experimentation in air. Under more highly oxidizing conditions, or in the presence of severe corrosion, these higher alloy steels would show to greater advantage because of their increased surface stability.

Conclusions

In this discussion attempts have been made first to set forth the characteristics steels must possess for satisfactory high temperature service and to indicate how these required properties vary not only in different industries but in different applications within the same industry.

The more common alloying elements were then classified and it was shown that some of them are suitable for increasing the high temperature surface stability and others for improving the strength of alloy steel. Certain also tend to produce a two-phased structure and, if this is not desired, the so-called ferrite and austenite formers must be balanced so that the resulting steel will be single-phased.

The way in which these alloying elements have been used in the development of high temperature steels was then reviewed, with the idea of showing that each element present serves a distinct and necessary function and that it has not been added simply for the purpose of making the alloys more complex or for increasing the number of steels available and thus complicating the picture for the designing engineer.

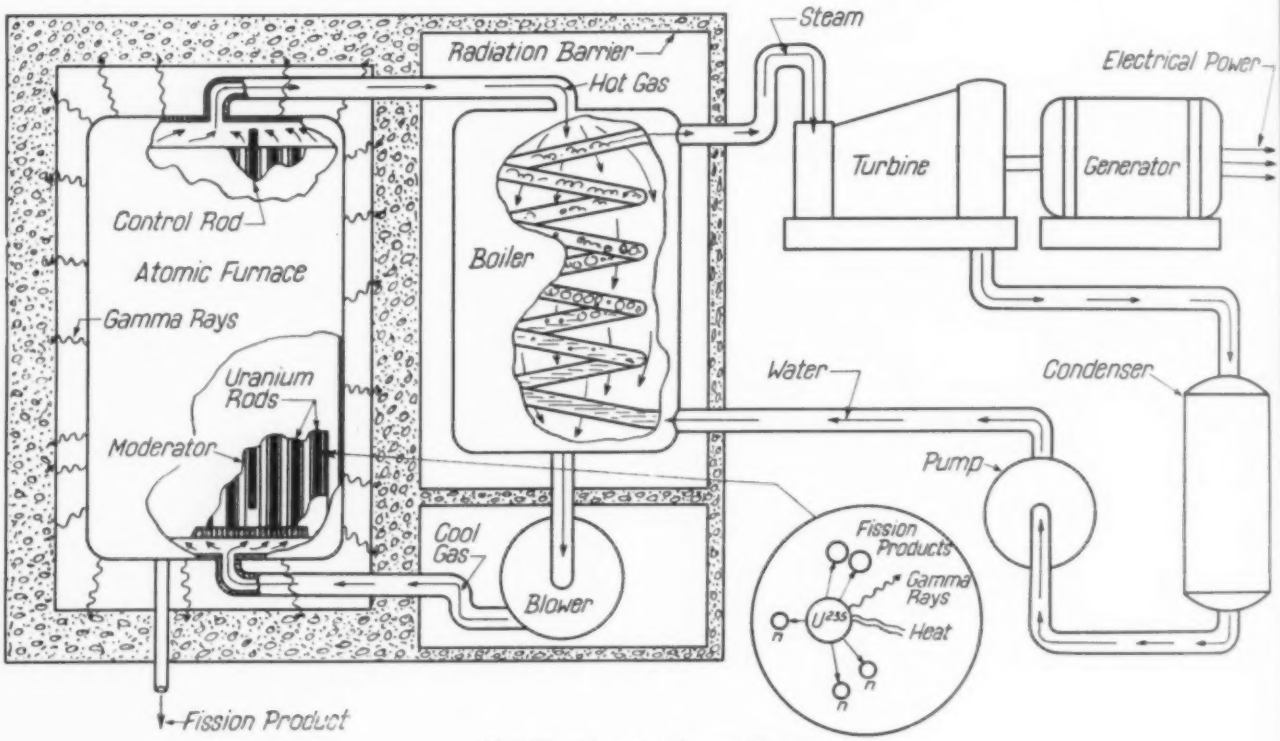
While the number of steels now available for high temperature service may appear to be excessive, a distinct need still exists for steels capable of withstanding more severe conditions of temperature and stress. This is especially true for continuous service at temperatures of 1500° F. and higher, and even for lower temperatures when the working stresses are large and the permissible amount of deformation is very small. The next few years should see considerable developments in this particular field as certain technological processes, now in the laboratory stage, could be applied commercially when such alloys become available.

Pierced Seamless Tube Emerging From Reheating Furnace, Enroute to Sizing Mill

Nuclear Power

ON September 5 BERNARD M. BARUCH, United States representative, transmitted a brief report on nuclear power to the United Nations Atomic Energy Commission, based on a study by CHARLES A. THOMAS, vice-president of Monsanto Chemical Co. (which operates the Clinton laboratories at Oak Ridge) aided by a scientific and engineering group. Costs were figured on a modified Hanford pile, on which much design and operating information is available, except that the power unit would operate at a higher temperature greatly affected by the large investment, which is reflected in the interest, depreciation and maintenance charges. . . . It seems reasonable that future development will result in a reduction in the investment and operating cost.

"It is not altogether a case of nuclear power versus coal, gas, oil or water power, because the nuclear power plant has advantages and fields of application not open to other types of power producing units." Only a trivial amount of fuel need be brought in and necessity for large amounts of



Daniels Atomic Power Plant

and all the plutonium formed would be recovered for later consumption in the pile. A complete plant, including all auxiliary equipment, to produce 75,000 kw. "could be built in a normal locality in the eastern United States for approximately $25,000,000; operating at 100% of capacity and figuring interest at 3%, the operating cost would be approximately 0.8¢ per kw-hr.

"This is to be compared with a coal power plant which would cost $10,000,000 under the same conditions. With high quality coal at $7 per ton delivered to the furnace, the operating cost would be approximately 0.65¢ per kw-hr. Equality of operating costs between coal power plants and nuclear power plants would be reached if the coal cost $10 per ton.

"The operating cost of nuclear power is cooling water may be avoided by using gas instead of steam turbines.

"It is the belief that a comparatively small standardized power plant will be developed. Such can be placed at strategic points on all established utility systems, and would greatly reduce power transmission costs."

A War Department news release on November 22 contained a diagram of a power pile, suggested by FARRINGTON DANIELS of University of Wisconsin, consultant to Clinton laboratories, and on which is based a pilot plant now being designed by the staff at Oak Ridge. (General Electric Co., which operates the Hanford works in Washington, is working on several different designs of nuclear reactors for the generation of electric power, but no basic design has yet been agreed upon. A gov

ernment-owned laboratory is being built at Schenectady, to be operated under contract by General Electric Co., to further these studies and to investigate the specific problem of ship propulsion by nuclear energy. Thus, two prime contracts have been awarded for the development of power, one to Monsanto Chemical Co.—to work at the Clinton laboratories at Oak Ridge, Tenn.—and to General Electric Co.—to work at Hanford, Wash., and at Schenectady.

Problems actively worked on at Oak Ridge are *(a)* the shape and size of the fuel unit, *(b)* the transfer of heat at 650 to 950° F. to the prime mover, *(c)* the method of loading and unloading the pile, *(d)* the automatic remote control of all equipment and *(e)* the protection of personnel against radiation. Emphasis must be laid on long life and great reliability, since any pile, once operating, is difficult and dangerous to shut down for maintenance. This first pilot plant is not expected to be in operation much before the end of 1947.

To quote the War Department's announcement:

"Although there is a remote possibility that, in the future, some of the energy available within the atom may be released directly through a medium other than a heat engine, such a device is not at present known. Atomic energy is simply a new fuel; current work is concentrated on adapting present power producing techniques and equipment to this new type of fuel. As matters stand, no element of a power plant can be omitted when nuclear energy is used to replace our present forms of fuel, although fuel handling equipment will be greatly reduced in size and may be omitted entirely in plants designed to operate for a limited time.

Difficulties in design and construction fall into four categories:

"Materials of construction must be found which possess strength, resistance to deformation, and ability to withstand very high temperature, but also have the additional quality of not breaking down under neutron bombardment.

"Theoretically, a suitable heat transfer medium or pile coolant may be ordinary water, heavy water, gases, or liquids other than water. Several liquid metals are being studied, but little is known of their properties from a nuclear and corrosive standpoint.

"Auxiliary and operating equipment must be developed. Pumps, blowers, valves and heat exchangers may become radioactive, and must be absolutely tight, trouble-free and require either no maintenance for extended periods of time or maintenance by remote control apparatus — which entails obvious difficulties.

"Protection of operators against neutrons and gamma rays is the fourth field of difficulty. The radioactivity emanating from a power pile is the equivalent of tons of radium; much of this persists even after the pile is shut down."

Correspondence

Sampling a Lot, and Life Tests

KIMBERLY, WIS.

To the Readers of METAL PROGRESS:

Two items in the August issue [both being due to The Editor's additions] are responsible for these comments.

The first is the footnote on page 289 of the article by F. J. Robbins on "Statistical Control Applied to Wrench Manufacture". The first two sentences of this footnote read as follows: "Many of those who have had no experience with sublot inspection have difficulty in accepting the idea that the quality of the uninspected material is the same as the quality of a properly inspected sample — at least to a very high degree of probability. (The same persons would doubtless accept the results of a chemical analysis of a proper sample of a shipload of iron ore, although the determination was actually made on an infinitesimal portion of the whole.)"

Perhaps the first sentence needs qualifying, because — except a lot is made under statistical control — we cannot estimate the lot quality from a small sample. If control exists, a small sample might contribute to an estimate, but many samples from prior lots would also contribute in aggregate a much larger share of the total information. Figure 1 of Robbins's paper, for instance, shows lack of control, so we have little knowledge of the source of any one lot and, consequently, are not justified in making statements about its uninspected portion nor in attaching any "high" probability values to the guesses we may make, even if our sample is perfect.

Referring to the second sentence of the footnote, I would perhaps agree that standard commercial methods of sampling bulk materials have some shortcomings. Yet what is the alternative to testing a "proper" composite sample of a shipload of iron ore? Such a composite gives an estimate of average quality. Another estimate could be obtained by averaging arithmetically the analyses of many por-

tions, but is one estimate any more precise than the other? Not if the sampling is "proper". There is no relief from the fact, in either procedure, that only a small portion of the lot is actually subjected to analysis. It is true, however, that the composite sample loses for us the opportunity of estimating the "within shipload" variability which would enable us to test the differences "between shiploads" for significance. The latter problem is generally not involved in determining average quality as a basis for payment, and it probably will not be until the umpires or purchase agreements require that the precision of our averages be stated.

The second item deserving of comment is in the "Critical Point" which discusses variability in tests on bearings. Viewing The Editor's remarks from the angle of statistical control, one might not be alarmed at wide variation in life of bearings — even the quoted "one to ten" — since such variability does not *of itself* indicate lack of control in processing. Perhaps it is characteristic of bearings, their manufacture and testing, to exhibit large variability in life within lots. If so, the appraisal between lots or between sources will require very large samples; it is possible to calculate just how large the sample must be in order to give any desired probability of detecting a difference of a chosen amount when it exists.

Similarity of life-to-failure curves to mortality curves used by insurance actuaries should surprise no one. Otto Almen has presented such curves for many automotive parts and for a "lot" of fatigue specimens. A mortality curve could be drawn for the folding endurance of the paper upon which *Metal Progress* is printed, and it would resemble that for ball bearings. Is this a "happen-so"? The quality control engineers have been telling us that qualities of many industrial products have been found to approximate the "normal" distribution when plotted as frequency polygons and the life characteristics such as fatigue strength of metals, fold strength of paper, wear of textiles, burning time of lamps, are no exceptions.

It is a simple matter to transform one of these life-to-failure frequency distributions into a life-to-failure cumulative distribution on a common basis with cumulative curves of other products. (All such curves show the per cent surviving against per cent of average endurance.) Some failures will always occur before others in any one lot of product, due to individual differences, so it is perhaps better to speak of reducing "within-lot variation" than of "infant mortality".

Reducing within-lot variation may take much doing, but it must be done if the engineer is to be relieved of the necessity of using excessive factors of safety. But even when lots of bearings of satisfactory average life, of very low variability within lots, and of statistical uniformity between lots are produced, the life-to-failure curves will appear to look like mortality curves.

Actually, that fact is one strong argument for application of statistical method to the analysis of industrial quality problems.

A. P. BELLINGHAUSEN

Phantom Halfback

CINCINNATI, OHIO

To the Readers of METAL PROGRESS:

Here is a picture of a Phantom Halfback that two of our students, F. Keiffer and F. Westermann, uncovered a couple of years ago in the examination

of a specimen of decarburized Nitralloy that had been nitrided. The picture was taken at a magnification of 1800 — perhaps a measure of the emphasis given the sport in certain quarters.

JOHN F. KAHLES
Asst. Prof. of Metallurgy
University of Cincinnati

Hydrogen in Metals

PARIS, FRANCE

To the Readers of METAL PROGRESS:

Important among the impurities always present in industrial metals and alloys are gases — particularly hydrogen. In order to understand how hydrogen influences the metal's properties it is necessary to know by what mechanism it remains fixed in the solid — in other words, the relationship between hydrogen and the structure of metals.

Our knowledge of this subject has progressed considerably during the past few years and the

problem has been much clarified by Professor Chaudron and his associates in France in their systematic study of the state of this gas in metals and their improved methods of adding and extracting hydrogen. In their studies they combined the use of metallographic analysis, X-ray crystal analysis, and tests of mechanical properties — particularly hardness and elastic limit. The conclusions of these investigations may be briefly summarized as follows:

At very low temperatures the hydrogen molecules (H_2) are superficially fixed according to the ordinary laws of adsorption, but as room temperature is approached these molecules dissociate at contact with the metallic surface resulting in a superficial fixation of atomic hydrogen which then diffuses in the metal, atom by atom. They, being very small, always seem to be able to find a place in the voids of the structure so there is no major transformation of the metallic structure.

Three sorts of voids in metal have been recognized into which hydrogen can diffuse:

1. Intergranular Voids — Between the various crystals or grains that make up the metal structure are amorphous or decrystallized zones which may harbor voids. Hydrogen diffuses rapidly in these regions. When they exist in iron alloys, inclusions or blowholes of molecular hydrogen will be formed under very high pressure. This phenomenon promotes the well-known pickling brittleness in iron. Under proper conditions of time and temperature, the gas in these pockets is reabsorbed by intergranular migration of the hydrogen toward the surface, and the metal then recovers its original mechanical properties.

2. Intercrystalline or Mosaic Voids — It is believed by many that metal crystals do not have a perfect network structure, but are formed by the juxtaposition of tiny, uniform crystalline blocks or microcrystallites (whose dimensions are at the extreme observable limit of the microscope, yet are much too large to be revealed by X-rays). When a single crystal of iron was exposed for many hours to cathodic hydrogen, a very fine division of the crystal was observed by Prof. Chaudron, seen only with the greatest possible microscopic enlargement. This gives experimental proof to the existence of the so-called superstructure in the iron crystal — more properly it should be called the "substructure", or "infrastructure" — and likewise provides an interpretation of some previous investigations on the solubility of gases in metals.

3. Interatomic or Network Voids — Palladium, which can dissolve a thousand times its volume of hydrogen, has been used to demonstrate by X-rays the insertion of atoms of hydrogen into the crystalline lattice or network. The dimensions of the unit cell increase in proportion as the atoms of hydrogen are inserted. Palladium can be so charged with hydrogen by making it the cathode in an electrolytic bath. X-ray investigations will reveal, in addition to the alpha-phase pattern of the palladium, a new and evanescent constituent (beta) that disappears very rapidly and whose structure does not differ from that of the palladium except in the value of the parameters. As the time of electrolysis increases, the parameters of the alpha and beta phases increase.

In conclusion, it may be said that metal possesses a sort of zeolitic structure, as far as hydrogen is concerned, in three scales — micrographic

State of Hydrogen in Iron and Its Influence

	Interatomic (in the Crystalline Network)	Intercrystalline (in the Mosaic Structure)	Intergranular (in the Micrographic Structure)
Hydrogen content	About 200 cc. per kg.	About 2000 cc. per kg.	About 200 cc. per kg.
Method of introduction	By low voltage electrolysis (less than 100 volts)	By electrolysis at voltages higher than 100	By acid attack of a polycrystalline metal
Extraction (cold)	By ionic bombardment	By ionic bombardment	In vacuum in a few hours
Effect on properties			
Hardness	None noticeable	Increases with gas content (reversible)	Irregular (reversible)
Modulus of elasticity	Increases 10% (reversible)	Rapid drop above 1500 cc. per kg. (irreversible)	Considerable drop (reversible)
Bend test	—	—	Decreases number of bends from 10 to 1 (at 200 cc./kg.)
Effect on structure			
Micrographic	None	A "superstructure" appears at 2000 diameters	Intergranular attack and blowholes (reversible)
Crystalline (X-ray)	None for iron, but very noticeable and irreversible with palladium	Fuzzy rays	None

or granular, crystalline or mosaic, and interatomic.

These various methods of combination of hydrogen help to explain the effect of gases on the physical and mechanical properties of metals, as outlined in the table [on page 1207].

ALBERT PORTEVIN
President
French Society for Metallurgy

Alphabetical Nuclear Physics or History Repeats Itself

LONDON, ENGLAND

To the Readers of METAL PROGRESS:

I have read and duly relished the account published in your journal (August 1946, page 310) of the researches on "Alphabetical Nuclear Physics" of Mr. Marmaduke Gwynne of the romantic spot known as Broken Hill Gulch, Utah.

Just for once, in a way, the old country has beaten the U.S.A. to it! In 1866, J. A. R. Newlands, at a meeting of the London Chemical Society, read a paper on "The Law of Octaves", which paper was one of the signposts to the periodic classification of the elements. At this meeting of the Chemical Society, Prof. G. C. Foster said that any arrangement of the elements would present occasional coincidences, and inquired if Mr. Newlands had ever examined the elements according to their initial letters.

I have always wondered how long it takes for a joke to be reinvented, and now I know: It takes just 80 years!

B. FULLMAN
Information Officer
British Nonferrous Metals Research Assoc.

"Brittle" Fracture of Ductile Metal

MOSCOW, U.S.S.R.

To the Readers of METAL PROGRESS:

Technical literature reaching us (sometimes greatly delayed) indicates that American testing engineers and metallurgists have given much attention to the so-called cohesive strength of metals. As an instance I would recall the symposium held in October of 1943 by the American Institute of Mining and Metallurgical Engineers. Maxwell Gensamer, one of the commentators, was quoted as saying that "this symposium demonstrates that cohesion failure cannot be treated in a very simple way, although some continue to treat it simply, in spite of its complexity". To the latter group I belong, as up to now it seems to me that the laws of fracture are simpler than generally believed, if the student takes into account that (at given temperature and loading speed) materials have not one but two cohesions: *(a)* tensile cohesion and *(b)* shearing cohesion.*

As I have developed at length elsewhere, the moment of rupture depends upon two ratios. One ratio is between the shearing stress s and tensile stress t $\left(\frac{s}{t}\right)$ as determined by the method of loading, shape of specimen and other factors. The other ratio is derived from the properties of the material — the shearing cohesion S_k and the tensile cohesion T_c — the ratio being $\frac{S_k}{T_c}$.

Under torsion and tension loads many ductile metals fail by shearing. The rupture of ductile metals, resulting from shearing in the presence of both necking and notch, often consists of many microscopic shears at an angle of 45° to the specimen's axis. Under visual examination, without magnification, these shears appear to be a rupture as a result of tearing off. Distinguishing between these two physically and mechanically different types of failure it is possible to explain many well-known facts:

1. When metals are tested in tension the presence of a notch increases the load at fracture if the metal is "ductile", whereas the load at fracture is decreased if the metal is "brittle". Ductile metals, under this circumstance, rupture by shearing (the influence of triaxiality); brittle metals rupture by tearing-off or tensile separation (the influence of stress concentration).

2. In torsion tests, toolsteels appear to have a very high strength — for example, Kennedy's data indicate shearing cohesion S_k of 340,000 psi. — whereas in tension and bending tests, toolsteels have very low strengths. The latter tests measure the tearing-off strength. This combination of very high shear strength and low tearing-off strength explains the different directions taken by the curves plotted by Luerssen and Green in their well-known investigations of impact bending and impact torsion.

3. In some metals there is a significant difference in the cohesive strength as the velocity of load and the temperature of testing are varied. In some other metals the change is small under parallel tests. This is due to the fact that the tensile cohesion is little influenced by the rate and

*EDITOR'S FOOTNOTE — Dr. Friedman, the correspondent, has written extensively in Russian technical literature on the testing of materials, both from a practical and a theoretical standpoint. His recent book (in Russian) on the "Deformation and Fracture of Metals Under Static and Dynamic Loadings" was given a long and favorable review in *Metallurgia* for September 1946.

temperature of testing, while the shearing cohesion is very sensitive to those extraneous factors.

4. Strain hardening greatly increases the tensile cohesion, but it has only a moderate influence on the shearing cohesion.

5. After tempering at a higher temperature the tensile cohesion of steel generally is raised a little and the shearing cohesion lowered a little. Among steels of different carbon contents, the higher carbon steels usually have higher shearing cohesions and smaller tensile cohesions.

These instances are enough to support my contention that many of the difficulties in a systematic review of the strength of materials are removed, and the problems of deformation and fracture are considerably simplified, when the student takes into account the existence of two cohesions (tensile and shearing) instead of one.

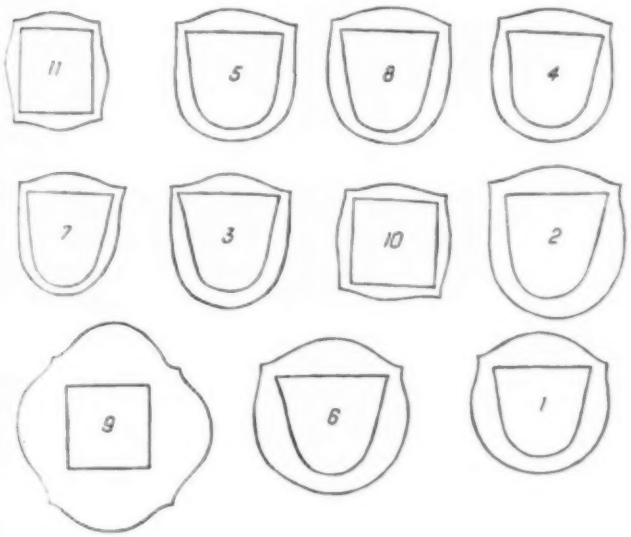
JACOB B. FRIEDMAN
Mechanical Testing Dept.
Institute for Aviation Materials

Plasticity in Experiment and Theory

NEW YORK CITY

To the Readers of METAL PROGRESS:

About seven years ago I tried to squeeze into my research work a tiny program of investigations covering the plasticity of metals. That program was cut short on its first day since the party that was footing the bills could see in it nothing but "pure science". However, I saved a few samples and pictures hoping to be able to continue that work later on. These hopes did not materialize, and in this communication I am merely trying to pass on my results for the use of other persons working in this field — under the assumption that such results might mean something to them — and to supplement them with some more-or-less related remarks on current attempts to generalize our body of experimental metallurgical knowledge.



Now for the experiment:

At that time I had in my possession eleven control ingots of various copper-base alloys produced commercially by one of the largest refiners in the middle west. Some had square, others had U-shaped cross sections.

From these ingots I cut and planed down slices ¼ in. thick. These were annealed by heating to 1300° F., rapidly placed under a forging hammer and struck just one heavy blow. The flattened surfaces still carried traces of the original contours and these were traced on paper together with the new contours. These are reproduced and correspond to the following alloys:

1. Intermediate manganese bronze (about ¼ α, ¾ β).
2. High tensile manganese bronze (full β).
3. Aluminum bronze (10% Al, 1% Fe).
4. Aluminum bronze (9% Al, 4% Fe).
5. Aluminum bronze (11% Al, 4% Fe, 1% Mn).
6. Aluminum bronze (11.2% Al, 3.5% Fe).
7. Aluminum bronze (10% Al, 4% Fe).
8. Complex bronze (11% Al, 5% Fe, 5% Ni).
9. Tin bronze (18.5% Sn, 0.5% other elements).
10. Navy T tin bronze.
11. Navy G tin bronze.

Here are the points which I think might be of interest in the study of plasticity:

A. Although the temperatures of the slices could not be controlled accurately and the face of the overworked hammer was anything but mathematically flat, all slices spread in a most symmetrical manner.

B. The amount of spread corresponded well to the nature of each alloy.

C. The spread was maximum in directions perpendicular to the flat side-surfaces, minimum at the sharp corners, intermediate perpendicularly to curved surfaces, and the sharper the curvature of the original boundary the smaller was the spread.

D. The angles of the corners seem to have changed very little, if at all.

E. The tin bronzes, except Navy G, exhibited many cracks, very unevenly distributed, but the cracking of the edges did not influence the amount of the spread in the directions toward such edges.

The above observations are somewhat cursory and of course are far too few for reliable conclusions. Nevertheless they serve to introduce some remarks along a line that has occupied a portion of my thoughts for some years, directed and modified by many other observations and from the study of literature.

Now for the observation about the theory of plasticity:

In addition to the practical metallurgists who are solving plasticity problems by skillful experiment, there are many others who "solve" them by writing out columns of equations and expressions containing nothing but factors irreducible to figures. The more abstruse such a column of equations becomes the more it is liked in some quarters. Just as in an old Russian story, where three vacationing students of the theological seminary were singing Latin songs under the windows of an old Cossack. The latter listened, then began to cry bitterly and said to his wife: "Please give the scholars a couple of loaves of bread, some cakes and a chunk of ham; their songs must be wonderful, even if I do not understand one word of them."

I would be the last man to object to the mathematical treatment of the problems of elasticity and plasticity. I object, however, to the application of Newtonian mechanics, with the consequent examination of axial, radial and tangential stresses and corresponding instantaneous accelerations. I maintain that what we apply to solid matter is not a system of stresses resolvable in three directions, but a system of energies, non-resolvable and distributed within that solid matter in correspondence with the distribution of its own energies.

As long, therefore, as the scientific metallurgist continues to use the fundamental notions of the Newtonian mechanics in his approach to phenomena taking place in solid matter, he will not be able to arrive at a clear understanding of such phenomena. For the Newtonian mechanics, precise when applied to phenomena in ordinary space, cease to be even a crude approximation when applied to that type of space which is called "solid matter".

MICHAEL G. CORSON
Metallurgical and Chemical Consultant

Variation in Properties With Size of 14 S-T Billets

SAN DIEGO, CALIF.

To the Readers of METAL PROGRESS:

The comments printed in August of L. D. Davis of the central metallurgical department of the Aluminum Co. of America, on the earlier article on "Brittle Failure of Hogged-Out Fittings From 14S-T Billets" by Given Brewer and myself, are very much appreciated.

His statements on the necessity of using "specially processed" hand forgings when maximum properties are desired from 14S-T forgings coincides with the conclusions we reached after making the tests outlined in the article. The engineering department of Consolidated Vultee Aircraft Corp. has instituted the practice of calling for "unit hand-processed forgings" when high physical properties are desired.

In answer to Mr. Davis's question as to the method of reworking the 11x16x20½-in. billet, an explanation is given on page 570 of our article in the March issue. The original 10x20x72-in. billet received by us was a forging. The 11x16x20½-in. billet was also a forging, but it was saw-cut on two sides, so that it could have been forged in a larger unit. At that time procurement of material was difficult, and we had little knowledge of the previous history of material received.

As noted in our article, in order to correct the conditions found in the original hogged-out fittings, several of the 11x16x20½-in. billets were sent to Vernon Works of Aluminum Co. of America and were reforged there, an attempt being made to get as close to the rough dimensions of the fitting as was possible with flat dies. The billets were upset to approximately a cube, then drawn out, this procedure being repeated three times. After forging, the parts were heat treated to the 14S-W condition, machined, and finally aged to 14S-T condition.

H. C. IHSEN
Development Engineering
Consolidated Vultee Aircraft Corp.

Shot-Peening of Springs

LOS ANGELES, CALIF.

To the Readers of METAL PROGRESS:

In the Correspondence pages of the October issue, Alberto Oreffice presents some interesting data on the fatigue life of shot-peened springs, and uses these data to support his statement that "rather large claims for the process [shot-peening] are made . . . [which are] . . . too optimistic". In particular his tests show life increase of 30% as against claims of life increase up to 1000%.

It seems to me that Mr. Oreffice's tests in no way disprove the older claims. He is jumping to the entirely unwarranted conclusion that the life increase at operating stresses will be equal to the increase shown in short life, high stress tests.

It is well known that the static strength of otherwise equally made machine parts is not increased by shot-peening, but that the endurance limit of such parts *is* raised. At the static ultimate stress the life increase is zero. At an alternating tensional stress above the endurance limit of the unpeened piece but below the endurance limit of the peened piece, the life increase can be shown by adjusting the test stress to suit.

A complete picture of the benefits of shot-peening therefore cannot be given in a single number, nor even in an S-N curve. The numbers quoted by

men such as F. P. Zimmerli of Barnes-Gibson-Raymond, and Robert Schilling of General Motors, are based on tests made at or slightly above the operating stress and are therefore significant.

It is an axiom of life testing that test failures must correspond in type and in approximate number of cycles to actual service failures. Highly accelerated tests such as those quoted by Mr. Oreffice are full of pitfalls; one cannot accurately infer the endurance limit from the static strength, nor the life ratio at 100,000 cycles from the life ratio at 224 cycles. This is true for the effect of scratches and stress raisers as well as for the effect of shot-peening.

As to Mr. Oreffice's service experience (which showed small life improvement), it is my guess that his springs were not peened correctly; obviously this must be done properly to be effective.

FRED K. LANDECKER
Manager, Metal Improvement Co.

Platinum Refining and Melting

SAN FRANCISCO, CALIF.

To the Readers of METAL PROGRESS:

In the September issue, C. C. Downie brought up the question of refining and melting of platinum, saying at the same time that an extreme secrecy is maintained by most platinum refiners concerning the processes employed. In other words, his claims may be summarized into the statement that there is no practical information available throughout the technical literature which describes the process of refining or melting of platinum and its alloys.

Well, this depends on what Mr. Downie has in mind: If he considers something similar to a cook book, then the answer is "No". If he considers the literature on the subject written in technical language and based on such branches of science as chemistry and metallurgy, then the answer is "Yes". Moreover, there is a great deal of such information printed in many languages, including the English. There is no question that purification of the six metals of the platinum group is a simple procedure, but one possessing a sufficient knowledge in inorganic chemistry and metallurgy will be in a position to find a suitable method in technical literature which will cover in detail his particular requirements.

Mr. Downie's statement concerning the failure to adopt the induction furnace for melting platinum and its alloys is also, from my point of view, far from being correct, as I am aware that such furnaces are now used for the purpose by platinum metal producers throughout the world. It also may be stated that, employing a standard unit consisting of 3-lb. capacity induction furnace and 20-kw. converter, it is possible to melt very conveniently as much as 100 oz. of platinum or platinum-base alloys in 15 to 20 min. As for a smaller melt, the units consisting of 6 or 3-kw. converter and the corresponding size induction furnace may be employed.

Concerning the procedure of extraction and separation of platinum from other metals of the platinum group outlined in so simple a manner — it appears to me to be oversimplified indeed, and the person who is familiar with commercial processes will be much surprised to read such recommendations. It must be remembered that besides precipitation of platinum with NH_4Cl, steps must be taken to prevent co-precipitation of such members of the platinum group as iridium. There are also steps which must be taken to purify precipitated platinum so as to remove iron which may contaminate platinum during the course of refining. In addition to this, there is a complicated process of purification of rhodium, ruthenium and iridium which Mr. Downie omitted mentioning.

M. B. VILENSKY
Research and Consulting Metallurgist
Owens-Corning Fiberglas Corp.

Antiquity of Lost-Wax Process or Who Is Metallurgicus, Where Is He?

ENILOM, USONIA

To the Readers of METAL PROGRESS:

The "Correspondence" column of the September issue features an article on the lost-wax process from Mr. Metallurgicus, supposedly from Enilom, Usonia.

The present writer has been a member of the ⊕ Chapter at Enilom for many years, and no one in these parts has ever heard of Metallurgicus. It is feared that The Editor has allowed an impostor to worm his way into his confidence. We people of Enilom are proud of our town and are leaving no mossy stone unturned to find this worm. If successful, we will expose him to all readers. Our chief worry is that the impostor may have feared our wrath and left this place hurriedly for points East.

F. C. TREWE
Enilom, Usonia

The Nitriding of Steel

By Carl F. Floe
Assoc. Prof. of Physical Metallurgy
Massachusetts Institute of Technology
and Assoc. Technical Director
The Nitralloy Corp., New York City

SURFACE HARDENING of steel by nitriding is a comparatively new process, dating back only to 1927 when patents were first issued to Fry in Germany. For several years the tonnage of steel treated was small, but recently it has increased very rapidly, going from 6000 tons in 1939 to 30,000 in 1941, nearly 100,000 tons in 1943, and doubtless even more in 1944. (These tonnages given are for the aluminum-containing steels only, and do not include S.A.E. steels, stainless, high speed, or chromium die steels, some of which are nitrided in considerable quantities.)

The reason for the increased use of the process is not difficult to find since parts so treated have a combination of properties that is particularly desirable for many engineering applications. The principal advantages are *(a)* a remarkably high surface hardness is obtained without subsequent heat treatment, *(b)* this hardness is maintained after heating to as high as 1100° F., *(c)* the wear resistance of the nitrided surface is exceptionally high, *(d)* the tendency to seize or gall is low, *(e)* a minimum of warpage or distortion occurs during hardening, and *(f)* the fatigue resistance of the steel, particularly the notch sensitivity, is improved.

Briefly, the nitriding process consists of heating steels of special composition in contact with a nitrogen-containing medium at temperatures from 925 to 1050° F. for periods ranging from a few minutes to 100 hr., depending upon the steel being treated and the depth of case desired. For successful results the steel must contain elements in solid solution that are capable of forming nitrides, such as aluminum, chromium, molybdenum, vanadium, tungsten, manganese or titanium. Nitrogen from the nitriding reagent, diffusing into the steel, forms nitrides with these special elements which, at the heat treatment temperature, are precipitated along the crystal planes of the iron. It is this precipitation of alloy nitrides which produces the hardened case.

A typical installation, diagrammed in Fig. 1, consists of a source of ammonia, a furnace, a sealed work container, provision for the circulation of the gas within the container, and equipment to control both temperature and gas flow.

Nitriding Media

Ammonia — The most common source of nitrogen for nitriding is ammonia. When it is heated to about 975° F., decomposition takes place at the steel surface in accordance with the following reactions:

Ammonia = atomic nitrogen + atomic hydrogen
$NH_3 = N + 3H$ (1)

Atomic nitrogen = molecular nitrogen
$2N = N_2$ (2)

Atomic hydrogen = molecular hydrogen
$2H = H_2$ (3)

Both the atomic nitrogen and atomic hydrogen of reaction (1) are unstable and pass rapidly to

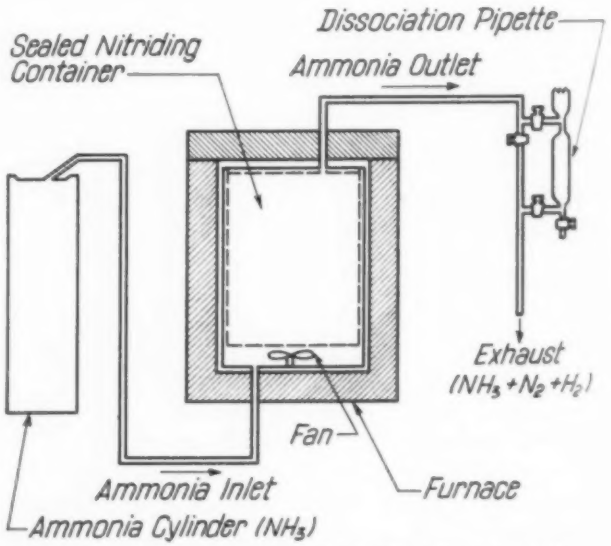


Fig. 1 — Diagram of Typical Nitriding Installation Using Ammonia as a Source of Nitrogen

the molecular form as illustrated by (2) and (3). It may, of course, be argued that neither the nitrogen nor the hydrogen ever exists as independent atoms even in the adsorbed layer at the gas-solid interface, but such an argument is of little interest as far as this account is concerned. The main point is that in the molecular state the nitrogen is completely inert and contributes nothing to nitriding. However, between the time that it leaves the ammonia and its passage into the inert molecular form, a part of it is absorbed by the steel. It may thus be seen that for successful nitriding it is necessary to insure an adequate supply of atomic nitrogen at all times, which can only be accomplished by continuously bringing fresh ammonia into contact with the steel surfaces. If this is not done, the available ammonia will soon be transformed to inert molecular nitrogen and hydrogen and action on the steel will cease. Therefore it becomes very important to circulate ammonia so as to supply fresh gas continuously to all areas to be hardened.

To insure an adequate supply of atomic nitrogen at the steel surfaces, ammonia is usually allowed to flow through the container at such a rate as to maintain a concentration of 70% ammonia and 30% nitrogen plus hydrogen in the exhaust gas. This is commonly spoken of as "maintaining the ammonia dissociation at 30%". However, due to the increase in total gas volume during the decomposition, only 17.7% of the ammonia entering the retort is dissociated under these conditions. The balance circulates through the retort and is wasted. Of the 17.7% which is dissociated only a small fraction provides nitrogen which is absorbed by the steel. Later the effect of operating at a higher dissociation and thus utilizing more of the ammonia will be shown.

One of the principal costs of the process is the cost of ammonia. The amount of this gas necessary per pound of work is primarily dependent upon the surface area, the dissociation used, the amount dissociated by the container walls and work fixtures, and the time at temperature. Excessive consumption can usually be attributed to operating at low dissociations or to excessive dissociation by the container walls and fixtures. In practice the consumption varies considerably but is usually from 20 to 30 cu.ft. per 100 sq.ft. of steel surface per hr. when operating at 30% dissociation.

Salt Baths* — The use of baths for nitriding has increased in recent years. In a general way it may be said that salt bath nitriding has the same relation to ammonia nitriding that cyaniding has to gas carburizing. If shallow cases are to be produced with short time cycles, or if the parts are small and the production low, salt baths have particular advantages.

The salts used are cyanides mixed in such proportions as to melt below the nitriding temperatures. A common composition is 60% sodium cyanide and 40% potassium cyanide. Under operating conditions these baths become partially oxidized, so they contain, in addition to cyanides, cyanates and carbonates of sodium and potassium. Typical reactions in nitriding are believed to be

$$2NaCN + O_2 = 2NaCNO \qquad (4)$$

$$2NaCNO + O_2 = Na_2CO_3 + CO + 2N \qquad (5)$$

Again, as in ammonia nitriding, the active nitrogen formed by reaction (5) is partially absorbed by the steel and partially reacts to form molecular nitrogen which is inert. Fortunately the sodium carbonate formed at the same time can be readily frozen out of the bath after a concentration of about 15% has been reached. To maintain a sufficient concentration of active nitriding reagents in the liquid, therefore, it is only necessary to add cyanide salts from time to time.

Some metallurgists advocate the use of salt baths through which ammonia is bubbled. Such a method produces reducing conditions within the bath, so the mechanism is different from that given above, but possibly ammonia dissolved in the cyanide is again the active nitriding agent.

Claims have been made that much deeper cases are obtained in a given time with salt baths than with gaseous ammonia. As will be shown later, case depth is determined by the rates of diffusion of nitrogen from the white layer on the steel surface to the steel beneath. Conceivably this rate could be higher with the use of salt baths because of the decreased concentration of hydrogen. There has been some indication that the presence of hydrogen in ammonia nitriding decreases the diffusion rate of nitrogen and thus reduces case depth. The magnitude of this effect, however, is not great enough to account for the claim that very greatly increased depths of case are produced with salt baths.

Structure of Nitride Cases

As outlined above, the atomic nitrogen, which is absorbed at the surface of the steel, diffuses inward, reacts with the nitride-forming elements present in solid solution in the steel, and precipitates, thus forming the hard case.

The depth of nitride case depends upon how far beneath the steel surface the nitrogen has been able to diffuse during the nitriding period. The principle involved is that as the alloying elements are removed from solid solution by precipitation as nitrides, the nitrogen (which is constantly being supplied from the surface) diffuses further into the

*See the article by R. S. Komarnitsky in the October issue, page 665.

100 ×

500 ×

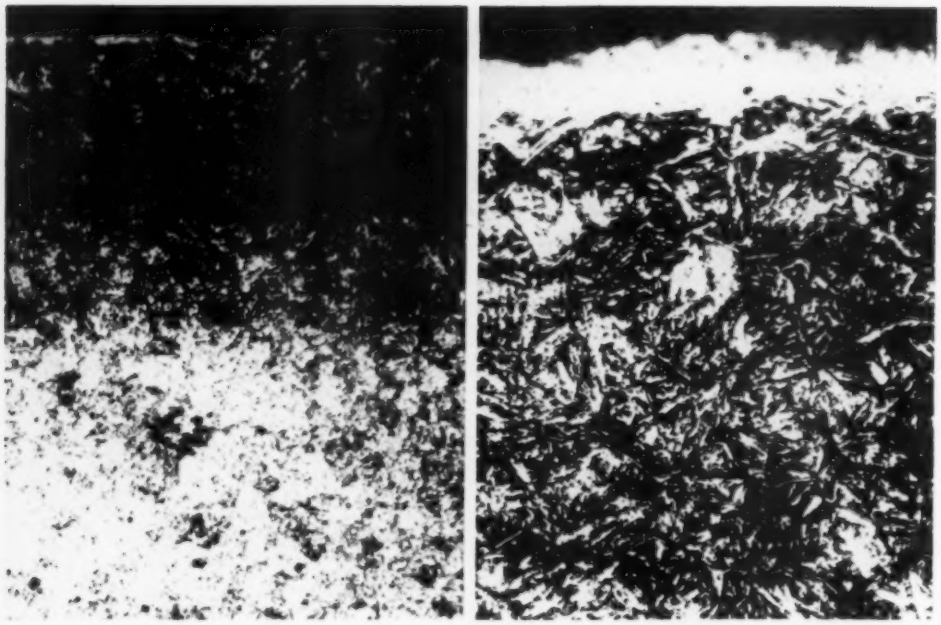


Fig. 2 — Microstructure of a Typical Nitride Case Showing the Surface White Layer and the Darkened Area of Useful Nitride Case: Nital Etch

alloy and thus produces an increasingly deeper case. The depth of case produced in a given time will therefore depend upon the amounts of alloying elements that must be precipitated out of a given region before the nitrogen can diffuse further.

A nitride case consists of two separate zones. The outer zone represents a region in which the nitride-forming metals, including iron, have been converted to nitrides. This region, which varies in thickness up to a maximum of about 0.002 in., is commonly known as the "white layer" because of its color after a nital etch. The useful part of the nitride case is *beneath* this white layer and represents the region in which the alloy nitrides have been precipitated. A typical microstructure is illustrated in Fig. 2. This shows not only the white layer but also the darkened area of useful nitride case, which represents the area into which nitrogen has diffused and precipitated the alloy nitrides, and (in the lower magnification) the unhardened core metal underneath.

It may be seen that the depth of useful nitride case is determined by the rate of diffusion of nitrogen out of the white layer to the region beneath. The nitriding medium, therefore, need only contain sufficient active nitrogen to maintain this white layer. Any increase in active nitrogen beyond this point will only serve to increase the depth of white layer and will not affect the depth of useful nitride case.

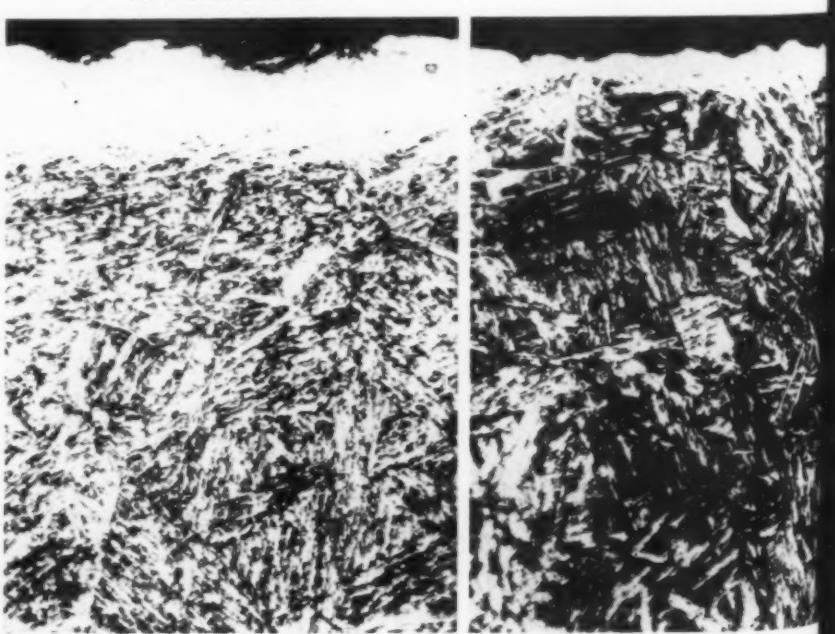
The concentration of active nitrogen on the surface of the steel, which determines the depth of white layer, is a function of the degree of dissociation of the ammonia. As previously mentioned, in normal nitriding this dissociation is held at 30% by adjusting the rate of flow. The effect of nitriding at higher dissociations, which gives a lower surface concentration of active nitrogen, is shown in Fig. 3. With increasing dissociation of ammonia, the depth of white layer decreases and becomes practically zero at 85% dissociation.

For some applications where it is impractical to grind or lap the parts after nitriding, it is desirable to decrease the depth of white layer as much as possible. This can be most readily accomplished by first nitriding at 30% dissociation for 5 hr. in order to establish the white layer, followed by allowing the dissociation to increase to 85%. With such treatment good case depth will be obtained with a minimum of white layer. The latter will be so shallow that there is little danger of chipping or pitting, and the surface should have a low coefficient of friction and low tendency for metal pickup. A typical structure produced by this method is shown in Fig. 4. It should be emphasized that if nitriding is carried out at high dissociations, there must be adequate

Fig. 3 — Effect of Ammonia Dissociation on Depth of White Layer in a Nitride Case. Samples nitrided for 36 hr. at 975° F. 500×

30% dissociation

65% dissociation



circulation within the retort during both periods. If not, the dissociation in some pockets may increase to the point where little or no nitriding will take place. Sufficient ammonia must be provided to all surfaces to maintain *some* white layer.

Variables — From a practical standpoint, all users of the nitriding process are interested in the variables which determine case depth and case hardness. The principal factors affecting the *depth* are:

1. The nature of the nitriding medium.
2. Time and temperature of nitriding.
3. Amount and nature of nitride-forming elements in solid solution in the steel — that is, aluminum, chromium, molybdenum, tungsten, titanium.
4. Amount and nature of inert elements — that is, nickel, silicon and carbon.

The role of the first two factors is obvious from the preceding discussion. Likewise for the third factor; the amount and nature of the nitride-forming elements in the steel affect the depth of case in that the penetration of nitrogen depends on the amount that has to be precipitated. The lower the alloy content the deeper the case that can be produced in a given time. This factor will be discussed further in connection with the types of steels that can be nitrided commercially.

Nickel and silicon in the steel (factor 4) affect case depth only insofar as they decrease the diffusion rate of nitrogen. Carbon in solid solution has the same effect; however, its most important influence is to combine with some of the other alloying elements to form carbides, thus removing them from solid solution and from the nitriding reaction. For example, chromium in ordinary steels will be distributed between the carbide and ferrite phases, and only that amount that is in the ferrite phase is available for nitriding.

The most important factors that influence the *hardness* of nitride cases are:

1. The depth of case.
2. The temperature of nitriding.
3. The amount and nature of nitride-forming elements in solid solution in the steel.
4. The structure of the steel before nitriding.

The apparent hardness varies with depth of case only insofar as the case is unable to support the hardness indenter. A shallow case is actually just as hard as a deeper one, but softer readings are

Fig. 4 — Structure of Nitride Case Produced by Nitriding for 5 Hr. at 30% Dissociation, Followed by 43 Hr. at 85% Dissociation

obtained due to the inability of the ordinary testing equipment to measure the hardness of such thin sections. For this reason a hardness tester employing different loads may actually be used to measure case depth.

The hardness of cases decreases with increasing temperature of nitriding. Maximum hardness consistent with good case depth is obtained by operating at 925° F. Much softer cases — but considerably deeper for a given nitriding cycle — may be obtained by nitriding at 1050° F. The commonly used temperature of 975° F. is a compromise between good hardness and satisfactory depth. However, for parts requiring extreme hardness with some sacrifice in case depth, a compromise temperature of 940° F. is recommended. Thread guides for the textile industry are an example.

Case hardness is largely dependent upon the size and amount of precipitated nitride particles. It will therefore vary not only with the temperature but also with the composition of the steel being treated. The magnitude of this effect is shown in Fig. 5, which gives the approximate case hardness obtained in steels containing various amounts of alloying elements. It should be noted that aluminum is the most effective and chromium second. It should further be noted that little hardness is gained by increasing the amount of alloying element beyond a few per cent.

The hardest and toughest nitride cases are obtained only if the steel is in a sorbitic condition — the carbide phase uniformly and finely distributed through the ferrite. If masses of free ferrite are present or if the surface is decarburized, the case is invariably brittle and tends to chip under the hardness indenter, and the observed hardness values are lowered.

Nitriding Furnaces

The two most important considerations in the selection of a furnace are its ability to maintain a uniform temperature within the nitriding container and provision for adequate circulation of the ammonia. Temperature variations should not be

more than ±10° F. for satisfactory results. Proper gas circulation over all steel surfaces to be nitrided is essential in order to prevent ammonia from decomposing in "dead" zones in the container to the extent that nitriding is stopped in those regions. The ordinary way of providing such circulation is by an internal fan. One of the commonest reasons for trouble is improper equipment, and the importance of using furnaces designed for nitriding cannot be overemphasized.

Another problem in the construction of nitriding furnaces is the selection of proper materials for the container and fixtures. If such parts are made from alloys that will nitride, their surfaces will also dissociate ammonia and thus increase the cost of the process. Instances have been known where most of the ammonia was dissociated by the container and fixtures with the result that the work was not nitrided properly.

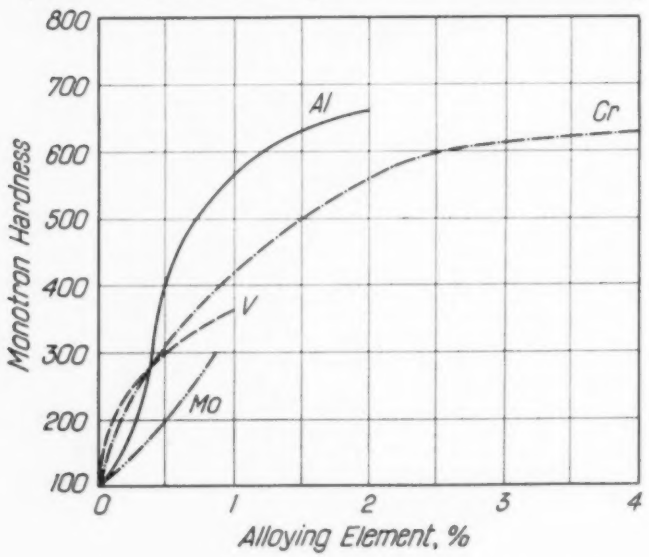
The best retort would be high temperature glass, but this is ordinarily impractical because of danger of breakage. Brick retorts are used and are satisfactory if the brick does not contain any iron and is not too porous.

The most satisfactory metallic material for containers is Inconel. After a considerable period of operation, however, this alloy may also begin to dissociate ammonia rapidly. To restore it to its original inert condition it is necessary to heat it to 1650° F. for several hours, and sand blast all surfaces. This should preferably be followed by reheating to 1650° F. in an oxidizing atmosphere. 35-15 stainless has also been used successfully but suffers from the same difficulties as Inconel.

Enameling of the metal surfaces is advisable, as it produces a permanently inert container, although one subject to damage by chipping.

Completely deoxidized copper retort fixtures are satisfactory but lack strength at the operating temperature. Ordinary tough pitch copper cannot be used because it becomes brittle after the copper oxide it contains is reduced by the hydrogen from the ammonia. Iron or steel is not satisfactory for fixtures because a surface which rapidly dissociates ammonia is soon formed.

Fig. 5 — Surface Hardness of Nitride Cases as a Function of Alloy Content, as Measured With a Monotron (Brinell Scale) According to French and Homerberg



Growth in Nitriding

An increase in volume occurs in the case as a result of nitride precipitation. To accommodate this it is necessary for the rest of the part to stretch, and this results in dimensional growth. The case pulls against and stretches the core and therefore after nitriding and cooling there will be compressive stresses in the case balanced by tensile stresses in the core. The magnitude of these stresses has been the subject of some experimentation but they have never been accurately determined.

It follows, from the mechanism explained above, that the magnitude of the growth will vary with the section size, the depth of case and the shape of the piece. Fortunately, for a given part and fixed nitriding cycle the amount of growth is nearly constant. Thus it is only necessary to determine it experimentally and then to make proper allowances in the finish machining dimensions prior to nitriding.

The phenomenon of growth in one way is fortunate in that it results in improved fatigue resistance and decreased notch sensitivity. The compressive stresses in nitrided surfaces counteract part of the localized surface tensile stresses which commonly originate fatigue cracks. In other words, before a fatigue crack can start in a nitrided surface the localized tensile stresses must exceed the compressive stresses by an amount sufficient to originate a crack. The improved fatigue resistance and decreased notch sensitivity of nitrided Nitralloy parts is indicated by the endurance limits:

Not nitrided, without notch	45,000 psi.
Nitrided, without notch	90,000 psi.
Not nitrided, with half-circle notch	25,000 psi.
Nitrided, with half-circle notch	87,000 psi.
Not nitrided, with V-notch	24,000 psi.
Nitrided, with V-notch	80,000 psi.

In nearly all instances fatigue cracks will not start at the surface but rather at the junction between case and core. The reason for this is evident, since it is the region of maximum tensile stress under bending load.

If extremely close dimensional stability is required in nitrided parts, certain precautions should be observed: After nitriding and cooling down to room temperature there is a balance

between the compressive stresses of the case and tensile stresses of the core. If this balance is upset by grinding off a part of the case, slow dimensional changes may occur in service as the stresses tend to reach equilibrium. To prevent this, parts should be reheated to the nitriding temperature after grinding. Such treatment, however, is unnecessary unless *very* close dimensional stability is required. (It is undoubtedly true that in some instances such dimensional changes have been erroneously attributed to wear.)

Protection Against Nitriding

It is frequently desirable to protect certain areas of a given part against nitriding. This is commonly done by electroplating with tin. Parts are usually plated all over and the tin then ground from the areas to be hardened. The plate thickness should be between 0.0003 and 0.0005 in. Tin melts considerably below the nitriding temperature and is therefore held by surface tension only; if it exceeds 0.0005 in. thick, there is danger of "running" or dripping onto unwanted areas.

In grinding tin from areas to be nitrided, it is very important to keep the wheels clean in order to prevent tin smear on the finish ground surfaces. Such smears will effectively prevent nitriding. For detection of tin smears prior to nitriding, parts are frequently given an oxidation treatment such as bonderizing; any tin remaining on the surfaces will remain bright and can be readily detected. The oxidized surface is excellent for nitriding. Tin may also be applied in the form of a paint consisting of tin powder or tin oxide powder in a suitable vehicle.

Bronze plating may be used as a protection against nitriding. While the plating procedure is more difficult, the results are excellent and there is no danger of the plate "running" during nitriding. The tin content of the bronze may be as low as 2% but more commonly it is around 10%.

Recently copper plating has been proposed as a stop-off against nitriding.* When properly used successful results have been reported. However, some nitriders claim that it is difficult to obtain complete protection under all conditions. If complete protection is not obtained, the principal difficulty is the dulling of tools in subsequent machining operations on the soft areas.

Steels for Nitriding

As previously stated, any steel which contains nitride-forming elements such as aluminum, chromium, molybdenum or tungsten may be nitrided. The *hardness* of the case, however, is a function of the amount and nature of the nitride-forming elements present, while the *depth* of the case decreases with increasing alloy content.

The hardest nitride cases consistent with good depth are obtained with steels which contain aluminum, chromium and molybdenum. These are sold under the trade name of Nitralloy and are the most popular nitriding compositions. They are the only steels marketed in this country whose composition has been specifically designed to give the

*See a discussion of this matter, including plating methods, thickness, and effect of prior surface finish, by W. V. Sternberger and E. R. Fahy in *Metal Progress* for February 1945 (page 278), December 1945 (page 1311) and October 1946 (page 673).

Fig. 6 — Depth-Hardness Curves for "Nitralloy 135 Modified" After Nitriding at 975° F. for the Periods Shown. Samples tempered at 1250° F. prior to nitriding

Fig. 7 — Effect of Prior Tempering Temperature (or Core Hardness) on the Depth-Hardness Characteristics of "Nitralloy 135 Modified". Samples nitrided for 48 hr. at 975° F.

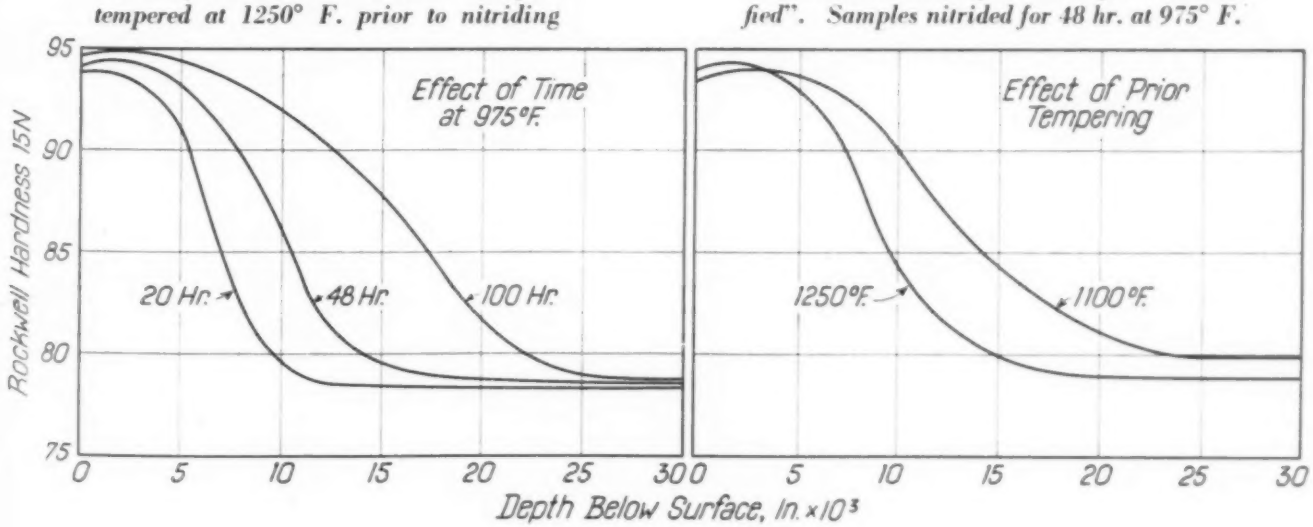


Table I — Typical Compositions of Steels Surface Hardened by Nitriding

Element	Nitralloy				S.A.E.		Stainless 18-8	High Speed 18-4-1	High Carbon, High Chromium	5% Chromium
	135	135 Modified	N	Graphitic	4140	X4340				
Carbon	0.35	0.41	0.23	1.25	0.40	0.40	0.10	0.70	1.50	1.00
Manganese	0.55	0.55	0.55	0.50	0.90	0.70	1.0			
Silicon	0.30	0.30	0.30	1.30	0.30	0.30	0.5			
Chromium	1.20	1.60	1.15	0.25	0.95	0.80	18.0	4.00	11.50	5.00
Aluminum	1.00	1.00	1.00	1.35						
Molybdenum	0.20	0.35	0.25	0.25	0.20	0.25			0.80	1.15
Tungsten								18.00		
Vanadium								1.00	0.20	0.40
Nickel			3.5			1.85	9.0			

optimum nitriding properties, combined with good core properties. Some of the S.A.E. steels, particularly those containing chromium and molybdenum or vanadium, are also nitrided both for improved wear resistance and improved fatigue properties. However, none of these steels gives as hard a surface as those which contain aluminum.

Typical depth-hardness curves for "Nitralloy 135 Modified", nitrided for the periods stated, are shown in Fig. 6, whereas Fig. 7 gives the effect of core hardness on the depth-hardness characteristics.

Several of the grades of aluminum-containing Nitralloy steels are manufactured to satisfy various engineering specifications, as shown in Table I. Of this group, "135" and "135 Modified" are most commonly used. The latter, due to its greater alloy content, produces a higher case hardness and somewhat better core properties. It is commonly specified for aircraft applications.

"Nitralloy N", containing nickel, is used if particularly high core properties are required. For development of the optimum core properties the practice is to quench from 1650° F. and temper at 1200, which produces a hardness of about 275 Brinell — soft enough for good machinability. During subsequent nitriding a case is produced in the customary way, but precipitation hardening also takes place in the core, forming a nickel-aluminum compound. This results in a great increase in the core strength and hardness as shown in Table II.

Table II — Core Properties of "Nitralloy N" Before and After Nitriding

	Before	After
Yield point, psi.	114,600	180,000
Tensile strength, psi.	132,400	190,250
Elongation in 2 in., %	22	15
Reduction of area, %	59.4	43.4
Brinell hardness	277	415

In the nitriding of "Nitralloy", S.A.E. and N.E. steels the core properties are first developed by quenching from the austenitic range followed by tempering to the desired strength and hardness. During the nitriding heat the core properties are not affected except for "Nitralloy N", as mentioned above. This preliminary heat treatment may be carried out on the bar stock or it may be done following rough machining; the two procedures are diagrammed in Fig. 8. The heat treated bar stock is often purchased directly from the mill.

Typical core properties of "Nitralloy 135 Modified" after tempering at several temperatures are shown in Table III.

Graphitic Nitralloy — A new development is a nitriding steel which contains free graphite. A typical composition is shown in Table I. This material may be either forged or cast in permanent molds. By a preliminary heat treatment (quenching from 1650° F. and tempering at 1375 for 5 hr.) approximately two-thirds of the total carbon is converted to free graphite. Thus the structure consists of about 0.8% graphitic carbon uniformly distributed through a matrix of carbide and ferrite.

Table III — Typical Core Properties of Heat Treated "Nitralloy 135 Modified"

Tempering Temp.	Yield Point	Ultimate Strength	Yield Ratio	Elongation in 2 In.	Reduction of Area	Hardness	
						Rockwell	Brinell
1000° F.	181,500	206,000	0.89	13.2	45.8	C-44.6	415
1100	165,000	181,000	0.91	15.5	54.3	41.0	368
1200	141,000	158,750	0.89	17.5	55.8	36.0	320
1300	125,000	145,000	0.86	20.5	64.5	32.0	285

as shown in Fig. 9. When such a structure is nitrided a typical case is produced except that the metallic structure contains pores, filled with loose graphite. It is believed that a material of this type will find many engineering applications, particularly where lubricated wear resistance is of primary importance. The soft graphitic phase seems to have lubricating properties of its own, or provides oil reservoirs for maintaining the lubricating film; the hard nitride surface provides maximum wear resistance.

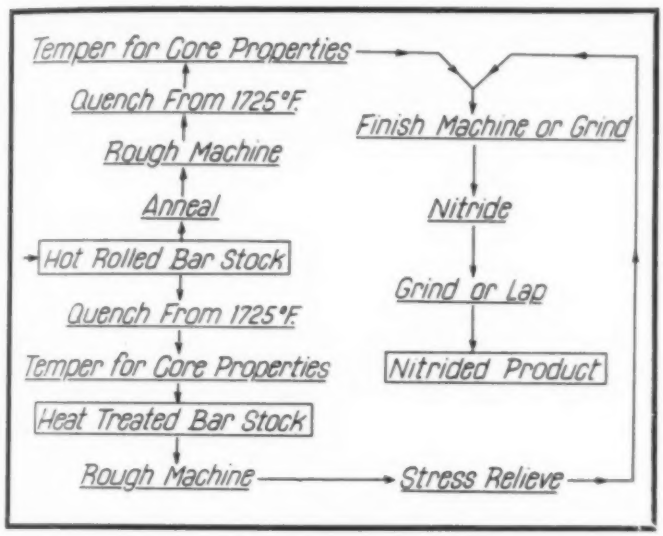


Fig. 8 — Outline of Processing Procedure for Nitriding Steels Other Than Stainless or High Speed Steels

Stainless Steel — Lately, considerable interest has been shown in the nitriding of stainless steels for applications requiring a combination of wear resistance and corrosion resistance. Hard chromium plate has ordinarily been used for this purpose, but plating is expensive, difficult to apply uniformly on irregular parts and often may have a tendency to peel off in service.

Stainless steels always contain chromium and sometimes molybdenum and tungsten and consequently they can be surface hardened by nitriding. However, several difficulties are commonly encountered. First, the alloy content is so high that shallow case depths are obtained. Second, the surface of all stainless steel is covered by a thin, adherent film of chromium-iron oxide which must be removed before any nitriding will take place. Third, the corrosion resistance of the surface is altered by the transformation of all of the chromium normally held in solid solution to the form of precipitated chromium nitrides. This is to be expected, since the corrosion resistance of stainless steel is due to the presence of chromium in solid solution in the iron. A steel in which the chromium has been precipitated as nitride does not offer the same resistance to attack. Salt spray tests show less resistance to corrosion after nitriding, and users of such materials should take this into consideration. The corrosion resistance of nitrided stainless is, however, somewhat better than that of other nitrided steels.

Several methods have been proposed for removing the layer of chromium oxide on stainless steel. These include heating at 800 to 1200° F. in dissociated ammonia, prior to nitriding; under these conditions the oxide is reduced by hydrogen. In some instances light sand blasting is used before the treatment with dissociated ammonia. Chemical destruction of the oxide film before nitriding is also practiced, usually by immersion in a 50% solution of hydrochloric acid in water at 150° F. for 5 to 15 min. (Parts treated by this method should be washed and immediately dipped in alcohol to prevent reoxidation; they should then be transferred to the nitriding container without drying and brought into contact with the nitriding gas without exposure to air.) Electrolytic cleaning prior to nitriding, for the purpose of destroying the oxide film, is also used.

Nitriding of 18-8 stainless is commonly carried out at temperatures of 1000 to 1050° F. Case depths of from 0.005 to 0.010 in. are obtained in 50 hr. on the 18-8 type; for the higher alloys the case is shallower.

The straight chromium grades of stainless steel may also be hardened. The depth of case produced for a given nitriding cycle is inversely proportional to the chromium content.

High Speed Steel — Considerable publicity has been given to the nitriding of high speed steel for tools, dies and gages. Unquestionably it increases the life of many types of tools, both because of the increased hardness and wear resistance, and because the more nonmetallic character of the surface reduces friction against metal and the tendency for metal pickup and built-up edges. Nitriding of cutting tools is, of course, ordinarily only of value until such tools are resharpened, unless resharpening is done on one face only. Care must be exercised not to chip the nitride case at the cutting edge while grinding. In some instances nitriding after each grinding operation may be necessary.

In the nitriding of high speed steel two of the same problems are encountered as in the treatment of stainless. First, an oxide film has to be destroyed. Second, the alloy content is high. The situation is much more favorable than for stainless, however, in that the oxide film is more readily removed by hydrogen from the ammonia and no special pretreatment is necessary. Furthermore,

while the alloy content is high, much of it is locked up in the carbide phase, and since only the alloying elements that are in solid solution enter into the reaction, the amount available to fix the nitrogen is much less than the analysis indicates. Consequently the depth of case produced in a given time is greater than would otherwise be expected.

Ordinarily, high speed steel tools are nitrided in salt baths rather than in ammonia atmospheres.* The nitriding time is usually short, from 5 min. to 5 hr. at 1050° F., which results in case depths varying from 0.0002 to 0.0030 in. More commonly periods of from 10 to 30 min. are used, the latter producing about 0.0010 in. case depth.

Control of time at temperature is easier in a salt bath. Furthermore the case is less brittle than when formed in an ammonia atmosphere. The reason for this is that the concentration of active nitrogen is less in a salt bath and consequently there is less tendency to form a brittle white layer. (As previously discussed, cases with a very shallow white layer could be successfully produced in ammonia at high dissociations.) Even salt baths form a thin white layer. If it is impractical to lap or grind, the brittle layer may be reduced by reheating to the nitriding temperature in a neutral atmosphere such as nitrogen, or in a neutral salt. Such treatment removes the white layer by diffusion and thus reduces brittleness and increases toughness.

All types of high speed steel may be surface hardened by nitriding. Before treatment it is necessary to harden, temper and finish grind in the customary way.

Many of the die steels which contain chromium and molybdenum (such as high carbon, high chromium, and 5% chromium steels) are also surface hardened by nitriding. Increased wear resistance is obtained and also decreased tendency for metal pickup. The latter is particularly important in drawing dies.

*See the article by W. E. Bancroft in last month's *Metal Progress* (page 945).

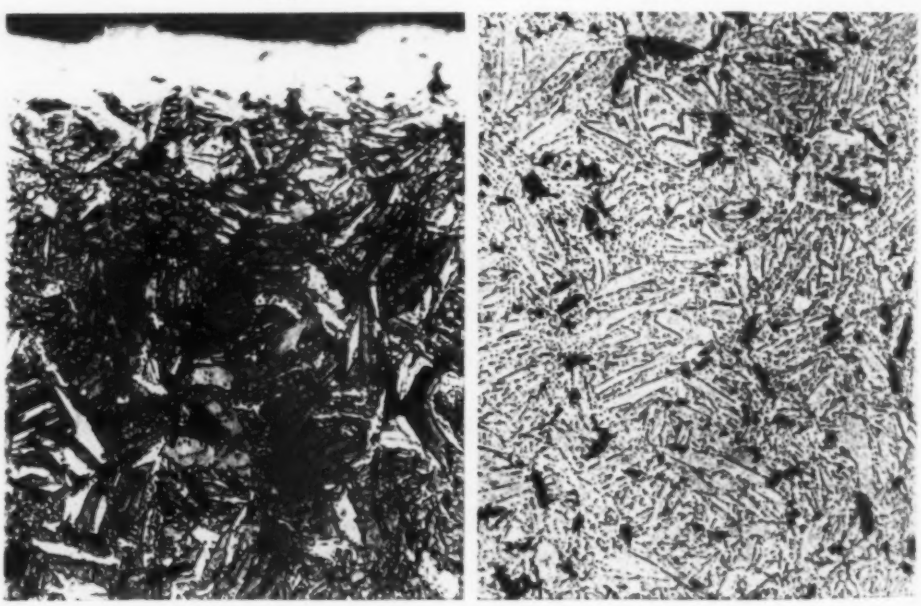
†The Nitralloy Corp. of New York City has issued an 86-page booklet "Wear of Metals" which discusses the mechanism of wear and the influencing factors.

Applications of Nitriding

The outstanding applications of the nitriding process are for parts requiring high wear resistance. This property is due not only to the high hardness but also to the ability to retain this hardness at temperatures which would soften conventionally hardened steels. The resistance to seizing or galling is therefore very much greater, and this accounts for the success of nitrided parts for applications where nonlubricated or poorly lubricated conditions exist. Examples of nitrided parts where wear is the primary consideration are very numerous. Some typical ones include cylinder barrels and liners, bushings, piston pins, rotors, shafts, shackle bolts, thread guides and spindles.†

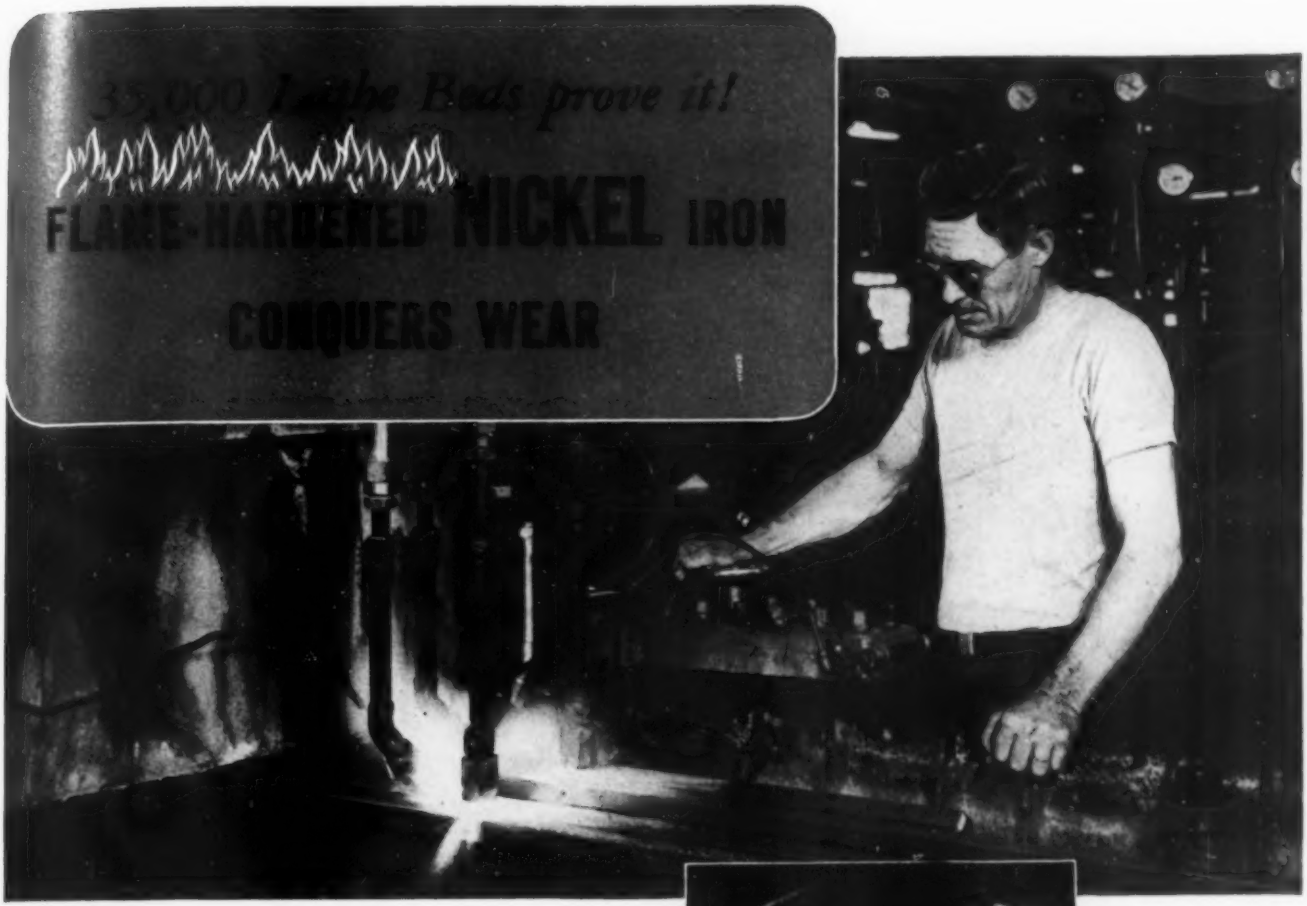
Examples of applications in which both wear resistance and freedom from distortion in harden-

Fig. 9 — Typical Microstructure of Nitrided "Graphitic Nitralloy", Showing Distribution of Free Graphite in Both Case and Core. 500×



ing are of primary importance include cams and camshafts, gears, gages, rubber and paper mill rolls, boring bars and crankshafts. It is obvious that in many of these applications the improved fatigue properties conferred by nitriding are also an important consideration.

Nitriding should therefore be considered for any parts in which the above properties are important. While the cost of nitriding steels is above that of the plain carbon steels, the difference is often more than offset by simplification in manufacturing procedure. If wear is a problem, nitriding can be the answer, particularly if maximum service life is the primary consideration.



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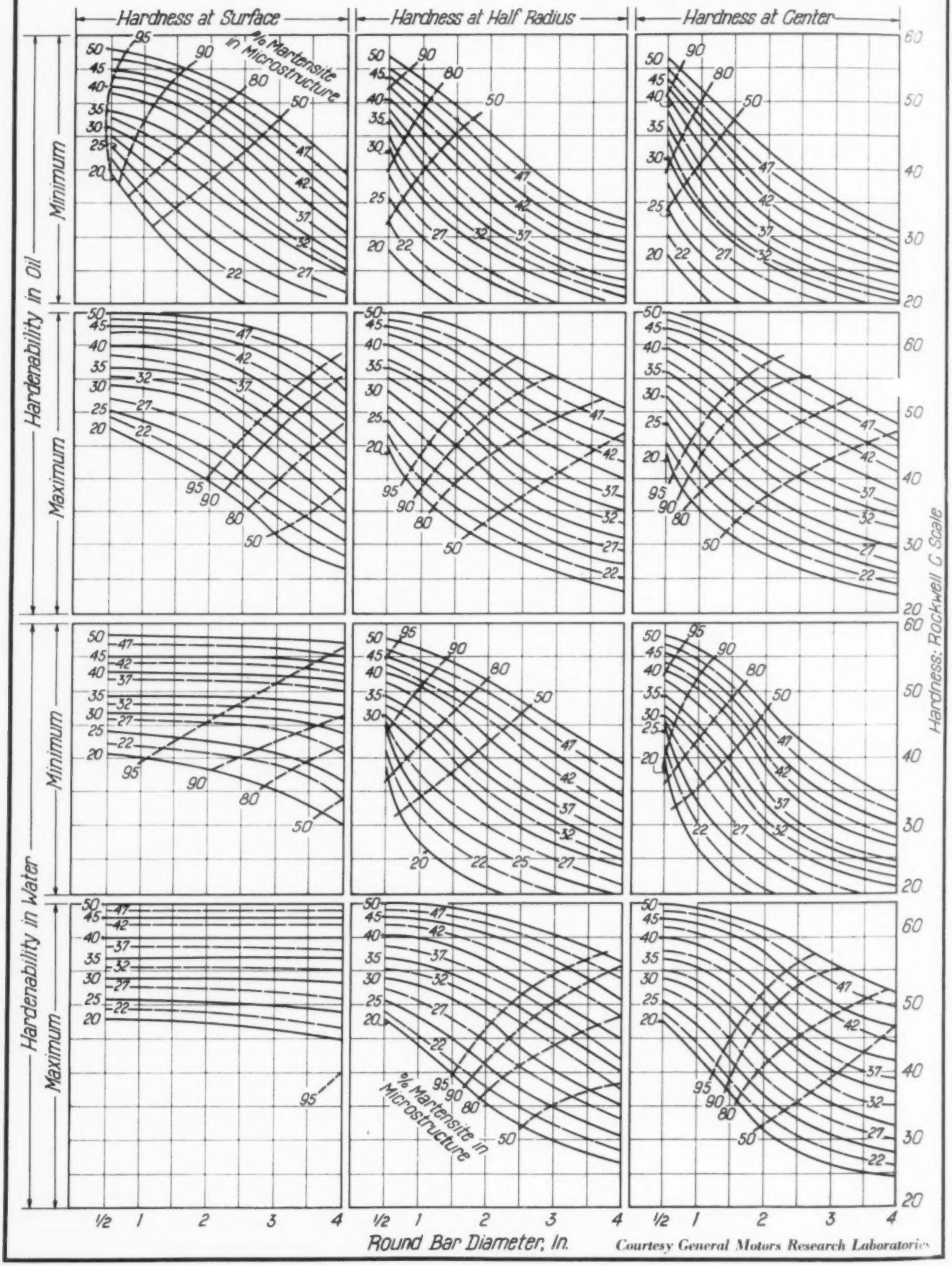
Hardenability of N.E. 8600 H Steels

By A. L. Boegehold

Mean carbon content shown on each curve



Courtesy General Motors Research Laboratories

Improvements in the Manufacture of Tin Bronzes

By W. T. Pell-Walpole

Chief Metallurgist, Tin Research Institute
Research Fellow, Birmingham University
Birmingham, England

A SERIES of researches on improving the quality of the group of alloys known by the general term of bronzes (copper-base alloys with tin as the chief alloying element) has been carried out during the war period in the University of Birmingham in England by the author and his colleagues of the Tin Research Institute.

The original object was to obtain bronzes in the wrought condition which would combine the established corrosion resisting properties of high-tin bronze with better mechanical properties than could be obtained either in these alloys in their normal cast condition or in lower-tin bronzes in the wrought condition. A serious discrepancy existed between theory and practice as regards the working ranges; according to theory, copper can hold up to 15% of tin in solid solution before any phase change occurs from the face-centered cubic structure and should — by analogy with other copper-rich solid solutions — be sufficiently malleable and ductile to be readily fabricated by normal industrial processes. In practice, however, there was considerable difficulty in fabricating any bronze containing more than 5 to 7% of tin.

This problem was clearly not new and had been the subject of many earlier investigations. In fact, according to various patents the problem had already been solved — although the solutions, if valid, had certainly not been adopted by British industry.

The literature on the subject (reviewed in an earlier publication in the *Journal* of the Institute of Metals, 1944, by the present writer) showed two main causes of difficulty in fabricating the high-tin bronzes:

1. In industrially cast ingots, the workable α solution was often encompassed by a surface layer of brittle high-tin compounds — the commonest example of the well-known phenomenon of inverse segregation.
2. The existence of gaps, cavities and fissures in the body of such ingots. These defects frequently occurred together in ingots, rendering them quite unworkable.

A host of theories had been advanced to explain these undesirable effects. Early workers principally blamed oxides and impurities, but gradually there grew up an overwhelming amount of evidence that the two defects listed above were in fact closely related and were caused by the evolution of gases from the liquid bronze during its solidification. Unfed shrinkage and entrapped air were considered secondary causes of porosity.

When this gas theory had been adopted, many workers began to try to find the gases responsible and methods of eliminating them from molten bronze and other copper alloys. Hydrogen was soon determined to be the chief culprit. The classical researches of N. P. Allen and his colleagues, published in 1933 in the *Journal* of the Institute of Metals, showed that in pure molten copper the amount of hydrogen which could be held in solution depended on the oxygen content of the copper, on the water vapor pressure in the atmosphere above the melt, and on the temperature of the metal. These results are summarized in Fig. 1, and point the way for a practical method of degassing copper and probably (by analogy) its alloys such as bronze.

This line of thought was followed by Lepp, first in Holland, later in France, and in his British patent. He showed that the oxygen : hydrogen relations in bronze were very similar to those worked out by Allen for copper, and that the hydrogen content of the metal could be reduced to a minimum, depending on the temperature and the water vapor content of the furnace atmosphere,

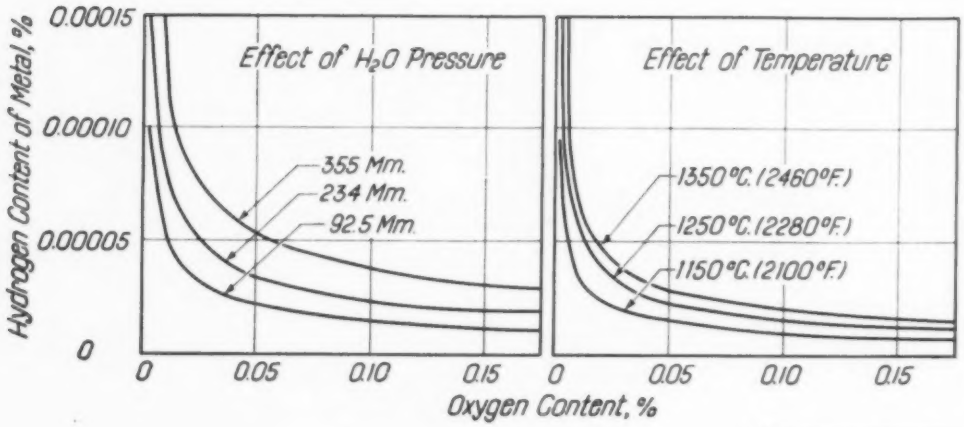
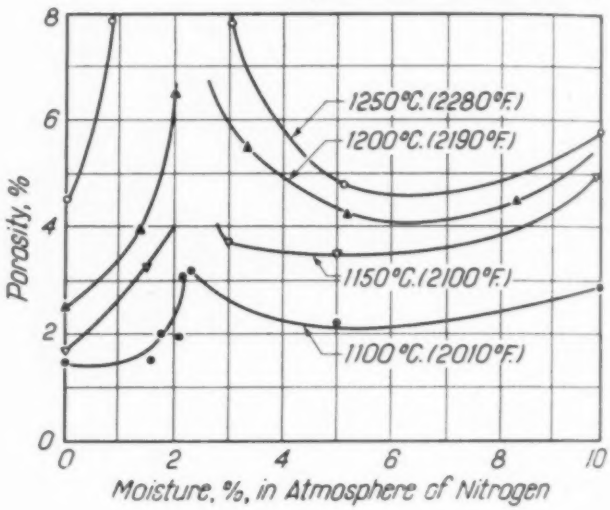


Fig. 1 (Left) — Relations of Oxygen and Hydrogen in Molten Copper, as Effected by Temperature and Water Vapor in the Furnace Atmosphere (After N. P. Allen)

Fig. 2 (Below) — Effect of Moisture Content of Furnace Atmosphere on Porosity in Bronze Sand Castings (After Pearson and Baker)



provided the melt contained sufficient oxygen. He therefore devised a flux consisting of oxides of copper and manganese in a carrier of basic carbonates also intended to remove sulphides. He also added small amounts of phosphorus or zinc to prevent over-oxidation of the tin. By use of this patented flux Lepp actually produced castings in tin-bronze containing up to 14% of tin which could be worked hot or cold.

At the same time (1929) W. Reitmeister in Germany had developed a similar degassing process in which he first oxidized the melt by CO_2 and then reduced it by CO generated from a mixture of oxide and charcoal.

Following these developments more fundamental work was carried out on gas-metal equilibria by Hanson and Wheeler at Birmingham. This was the direct forerunner of the wartime researches now to be summarized. Hanson and Wheeler established that traces of water vapor in the atmosphere could produce severe porosity in the metal, far greater than that which could be caused by equivalent hydrogen. The reaction

$$H_2O + Me \rightleftarrows MeO + 2H$$

proceeds first from left to right, the hydrogen being dissolved in the metal; then, on solidification, the hydrogen is ejected from solution and reacts with the oxides at the grain boundaries to form steam. If *all* gases were removed by vacuum melting, Hanson and Wheeler found that severe shrinkage porosity occurred.

This work was never published but was confirmed exactly by the work of W. A. Baker and his colleagues of the British Nonferrous Metals Research Association a few years later and published in the *Journal* of the Institute of Metals in 1941. Figure 2 is taken from this work.

It was clear from this that in order to avoid porosity in bronze it would be essential to eliminate first the hydrogen and then the oxygen and finally to devise methods of casting to avoid the occurrence of severe shrinkage porosity.

Degassing 10% Bronze

After discussion with Dr. Lepp it was decided to start by testing his process in the production of small billets (3 in. diameter, 1 ft. high). A massive refractory feeding head, to compensate for the contraction on solidification, was built onto a suitable chill mold (Fig. 3) and a charge of 10% tin bronze was prepared under Lepp's flux. After removal of the flux from the molten metal there was no sign of either oxide or of the bubbling flame spurts which indicate gas. Some billets were poured and the surface in the feeder head sank heavily and continuously until the metal was quite solid. Cooling was very slow, due to this massive feeder, but there was no sign of exudations of low melting constituents such as occur when gassy metal solidifies slowly. The billets were then sectioned and examined for density and porosity distribution. The lower portion of each was perfectly sound (density 8.87) but the upper third had large interdendritic shrinkage cavities along the axis. Clearly the precautions taken against shrinkage porosity were not sufficient.

This aspect of the problem was given further consideration and it was decided to apply the

principle of unidirectional solidification by designing a mold with a heavy chill base, insulating walls and a hot top. To avoid the need for the wasteful heavy feeding head, the principle of slow pouring was adopted. This arrangement (see Fig. 4) insured that there was only a shallow head of molten metal above the solidifying layer throughout pouring, thus preserving a steep temperature gradient in the vertical direction throughout the pasty zone between the liquid and solid, and so keeping this zone shallow. This facilitates the intercrystalline feeding required to compensate for the volume contraction on solidification.

This mold was designed to give billets 6 in. in diameter by 6 in. high. The particular aim was to obtain billets so uniformly sound from base to top that they could be extruded without any cropping.

Billets of 10% tin bronze, melted under Lepp's degassing process and poured slowly into this bottom cooling mold, were very satisfactory, showing no signs either of tin sweat or porosity. Sections had a density of 8.91 and the microstructure showed remarkable freedom from porosity and a very uniform distribution of the $\alpha+\delta$ eutectoid.

These billets were then annealed to absorb the δ constituent and, after a few trials to determine correct temperatures and pressures, were extruded satisfactorily at 700 to 750° C. (1300 to 1380° F.) to 1-in. diameter rod. The material had an excellent surface, a uniform fine-grained structure, and tensile properties of 67,000 to 72,000 psi. ultimate with 70 to 80% elongation. The material cold worked readily; after rolling and drawing to about 60% reduction it gave 170,000 psi. with 18% elongation. Corrosion tests, carried out by Dr. Cuthbertson at Manchester University, confirmed that this material was equal and in some tests superior to the best condenser tube materials available.

Thus it was demonstrated on a small scale that it was possible to obtain wrought bronze of high tin content with excellent corrosion resisting properties and with mechanical properties far superior to any commercial wrought bronze.

A number of practical difficulties had arisen in the course of these developments which had to be eliminated before such bronze could be produced commercially.

Flux Attack on Pots — The strongly basic Lepp flux attacked ordinary fireclay-graphite melting crucibles very severely, so that not more than six melts could be obtained from each pot. Carborundum, as an alternative, showed better resistance to flux, but tended to become slightly plastic at the temperature of operation. It is only fair to Lepp to state that he recommended that fluxed melts should be prepared in rotary furnaces having a bauxite lining. Unfortunately such furnaces were not generally available for bronze melting in Britain, while the need for improvement in the quality of bronze was urgent. On these grounds it was concluded that some less corrosive flux would have to be developed which retained the same oxidation action.

Deoxidation — A second difficulty with Lepp's combined degassing and deoxidation process arose with the necessity of treating melts consisting of all scrap. When the phosphorus content of such metal was low it was impossible to calculate the correct amount of deoxidant to be added during melting (as recommended by

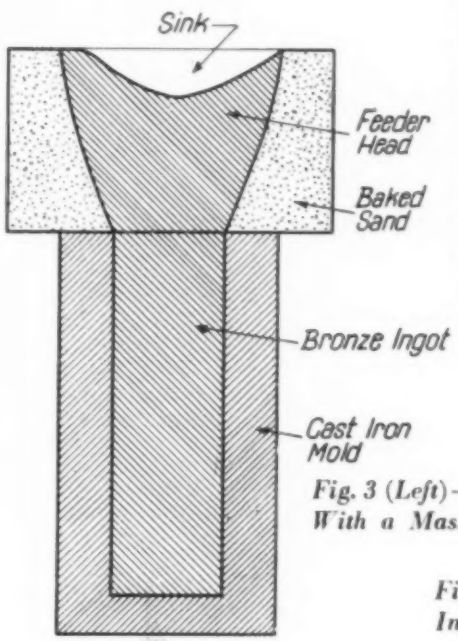
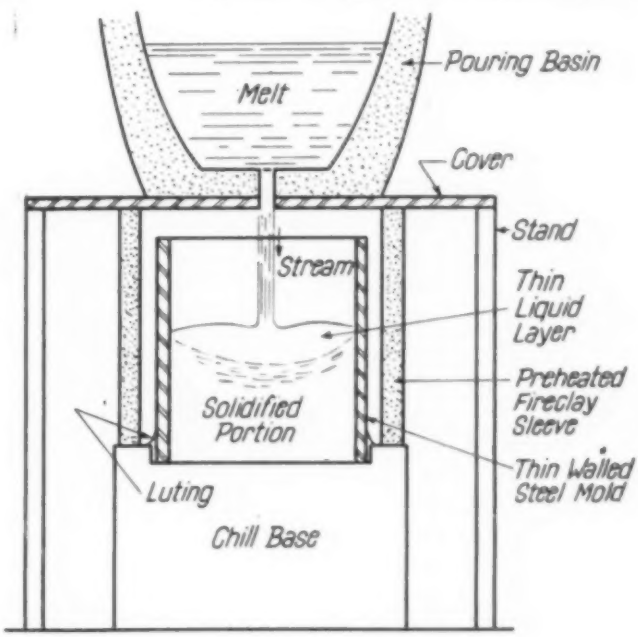


Fig. 3 (Left) — Cast Iron Mold With a Massive Feeder Head

Fig. 4 — Mold and Device for Casting an Ingot to Solidify in a Single Direction



him) and it was often necessary to add more deoxidant after removing the flux. This indicated the need for a quantitative investigation of the relationship between oxygen and phosphorus in the molten bronze, since final phosphorus content has an important effect on the hot working range of the product.

Mold Warping — A third difficulty was associated with the specially designed mold, Fig. 4. The thin-walled steel cylinder, used inside a preheated fireclay cylinder to prevent chilling of the ingot from the sides, began to assume a barrel-like shape after some 20 billets had been made, resulting in considerable difficulty in stripping. We needed some other type of mold wall which would retain the advantages of bottom cooling, but would either remain rigid or be of the collapsible type (sand walls) used for one billet only.

Thus, three secondary researches arose out of the original problem.

New Flux Process

In developing a new flux it was decided to use copper oxide as the oxidizing agent, as even a complete reduction of this oxide cannot contaminate the bronze. The carriers were required not to be basic in action at high temperatures, but to be stable, reasonably nonvolatile, capable of dissolving any oxide skins present in the charge, and readily separable from the molten metal before pouring.

Carriers — Sodium chloride, fluoride and borate, and boric acid were selected for test. They were tried, one at a time, and then — to ensure acidity — an equal quantity of silica sand was added to each and to various mixtures of these carriers. (The materials were sufficiently fluid at the operating temperature to stand a little thickening.)

The chlorides were rejected as they fumed badly and were very difficult to remove completely from the metal. Furthermore they trapped slag in the billets.

Fluoride alone fumed rather badly, but was much improved by the sand addition. This carrier was of particular interest as it was proposed to study aluminum as an alternative deoxidant to phosphorus, and the fluoride was expected to dissolve the Al_2O_3 reaction product. This flux attacked the pot slightly.

Borate and boric acid, tested alone, fumed much less than the preceding carriers but attacked the pot rather violently. With additions of sand, however, this disadvantage was completely overcome and the borax-sand mixture appeared to be the ideal carrier.

Copper oxide, in various amounts, was then tested and it was found that proportions of ¼ to ½ of CuO by weight were equally effective in obtaining complete freedom from gas (under the existing melting conditions, with a 10% tin bronze of low phosphorus content). Billets produced with the sand-borax-CuO flux, deoxidized with 0.075% phosphorus added after removing the flux, poured into the mold of Fig. 4, were comparable with those which had been produced by the Lepp process. They could be extruded or cold worked readily and gave equally high mechanical properties when tested in the wrought condition.

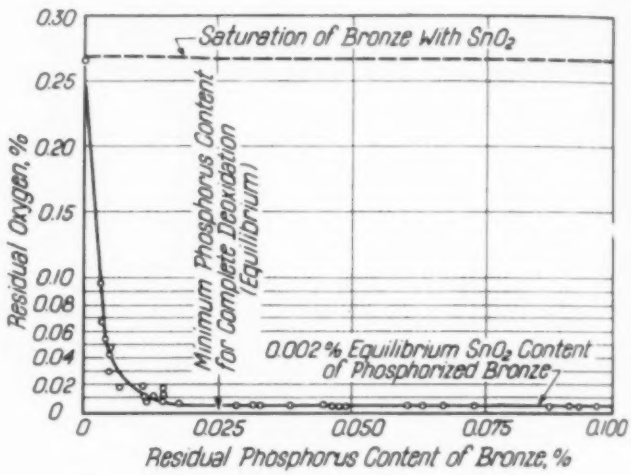


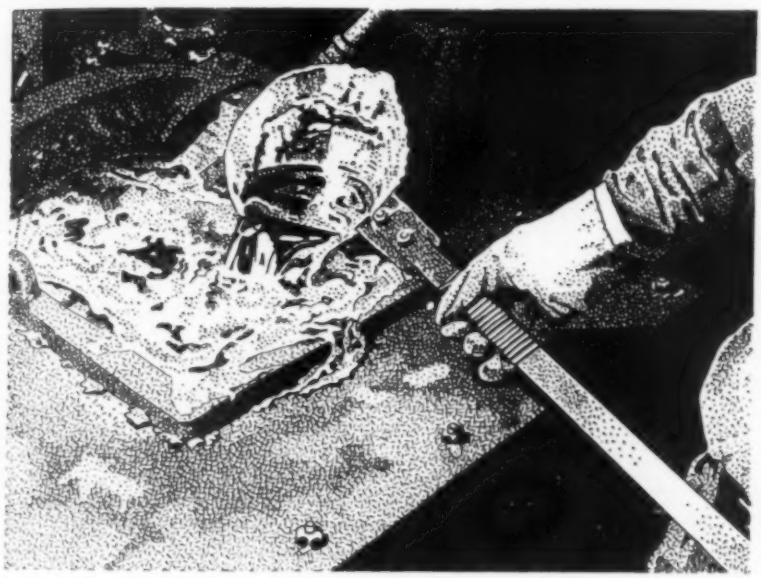
Fig. 5 — Relation Between Residual Oxygen and Phosphorus Contents of 10% Tin Bronze

This flux process gave more consistent results than other oxidation processes, including Lepp's or the direct addition of copper oxide to the melt, as recommended by Reitmeister, or melting with a strongly oxidizing flame.

Quantitative Control — A series of melts of 10% tin bronze were made under either sand-borax fluxes containing from zero up to 66% CuO under a charcoal cover, or without a cover but with a strongly oxidizing atmosphere. One melt prepared by each process was poured without deoxidation; to the others progressively increasing amounts of phosphorus were added. Ingots were analyzed for oxygen and phosphorus and examined for porosity, tin sweat and mechanical properties. This work, hitherto unpublished, showed:

1. *(a)* The oxygen content of the molten bronze was directly proportional to the CuO content of the flux used; *(b)* the amount of flux was unimportant provided there was sufficient for a complete fluid seal; *(c)* pre-fusion of the flux to remove all chemically combined water vapor had no effect on its available oxygen content.

2. The deoxidation reaction is a reversible one, subject to the law of mass action. A certain minimum equilibrium oxygen content can be retained in bronze, even in the presence of excess phosphorus (see Fig. 5) so that the presence of a trace of residual phosphorus is no guarantee of *complete* deoxidation, but a minimum residual phosphorus content of 0.02 to 0.025% is required to insure the *minimum* oxygen content. The phosphorus addition required to insure this condition was obtained for each of the covers tested, and it increases linearly with the CuO content of the flux.



Properties of the Bronze — Examination of the ingots showed that density and tensile properties were determined primarily by the initial oxygen content of the melt (which controls the gas content) and secondly by the efficiency of the subsequent deoxidation. These properties were lower in the melts produced under charcoal or neutral flux, irrespective of the amounts of phosphorus added. Melts produced under oxidizing fluxes gave erratic properties, rather low if no phosphorus was added, due to shrinkage porosity caused by entrapped oxide skin or intrinsic effects of brittle SnO_2 inclusions. With increasing additions of phosphorus these melts showed progressive improvement; density reached a maximum when the residual phosphorus content was greater than 0.02% — that is, the minimum phosphorus required to insure complete deoxidation.

Since both Allen and Lepp had shown that oxidation reduces the H_2 content to an equilibrium minimum but does not entirely eliminate it, while the above described tests showed that subsequent additions of phosphorus reduced the oxygen content to an equilibrium minimum, without entirely eliminating it, the recommended treatment must leave residual traces of both oxygen and hydrogen. These may conceivably react under favorable (or unfavorable) circumstances during solidification, causing traces of steam porosity — although, as the density shows, this must be very slight and does not impair the workability. However, if either of the reactants could be *completely* eliminated the quality of the billets and wrought products might be further improved.

Alternative Deoxidants — No simple and at the same time practical alternative for removing the hydrogen was available, other than oxidation; however, it appeared that deoxidation might be driven more nearly toward completion by using an element having a greater heat of oxidation than phosphorus. From the practical view it is important that use of such an element should not leave any harmful reaction products behind, more damaging than the last trace of steam porosity.

Of the elements available for trial aluminum was selected. Additions of 0.1%, after removing the flux, did give metal with a higher density (average 8.92 as against 8.88 for phosphorus) with slightly improved hot working properties. However, traces of Al_2O_3 inclusions caused weak spots here and there with local shrinkage porosity, thus comparing unfavorably with the notable uniformity of melts deoxidized with phosphorus. Extruded billets deoxidized with aluminum also gave slightly inferior results, due to these same inclusions.

Aluminum and phosphorus together were no improvement. While these tests still leave a wide field for research on alternative deoxidants, the use of an oxidizing flux followed by deoxidation with phosphorus provided, from the practical viewpoint, a quantitative control of the oxidation and reduction processes which, with virgin melts, was capable of consistently yielding bronze billets which could be extruded to give wrought products of very high quality.

Deoxidation of Scrap Melts — The next step was to obtain a similar degree of control with scrap melts containing phosphorus, so a series of melts containing various phosphorus content were made under fluxes with from 20 to 66% copper oxide. These showed that for each flux a constant proportion of the phosphorus in the charge was removed by oxidation during melting, the actual amount being proportional to the free oxy-

gen content of the flux. With this knowledge it was possible to adjust the final phosphorus contents so as to insure the minimum residual phosphorus required for complete deoxidation (to equilibrium). Provided this was done, billets from charges containing from 20 to 100% of scrap gave results fully comparable with those from billets made entirely from virgin metals.

Sand Wall Molds — There remained one practical aspect of the casting technique, namely, the need to modify the mold so that it could be used repeatedly. Experiments were made with sand wall molds baked at various temperatures. Billets were examined to determine to what extent the molten bronze had absorbed gas by reaction with the combined water in the sand.

Billets from a mold baked at 50° C. (125° F.) showed severe porosity throughout; its mechanical properties were as poor as those from metal which had not been degassed during melting. Billets from a mold baked at 100° C. (212° F.) showed similar properties in the outer layers but were quite sound at the center. When the mold was baked at 250° C. (480° F.) the billets had properties equal to those cast in the thin steel mold, except for a surface layer not more than ¼ in. deep which showed slight gas porosity (density 8.70). This is of little consequence in extrusion since a thin shell is left behind in the die. This procedure — that is, controlled oxidation followed by controlled deoxidation, and casting into the bottom cooling sand mold baked at 250° C. — was then used successfully for the large-scale production of billets for extrusion.

Tin Conservation — In view of the serious tin shortage which developed during the war, further experiments were carried out with an alloy containing 8% tin and 0.30% phosphorus. The degassing and casting procedures developed for the binary alloy were found equally satisfactory for this phosphor bronze, but the temperature range in which this alloy could be extruded was very restricted and therefore called for close control in actual plant practice.

Casting Billets for Strip and Bar

Having thus developed satisfactory and economical melting and casting procedures for producing billets of high tin bronze suitable for extrusion and subsequent cold working, the principles were next applied to the production of strip or bar ingots for rolling into sheet, rod, or bars, and for cold drawing to wires. The same melting technique was used, but (due to the shape of strip and bar ingots, in which the height greatly exceeds the cross section) it was impossible to apply successfully the new-found principle of chilling from the base only.

All strip and bar molds in industrial use were so designed that cooling proceeds from each mold face inwards; it was therefore necessary to introduce a different method to obtain freedom from shrinkage porosity. A study was made of the influence of rate and temperature of pouring, number and position of pouring streams, mold material, temperature and dressing on the extent and distribution of shrinkage porosity.* Rate of pouring was found to be by far the most important variable. Whatever the size, shape or material of the mold, complete freedom from shrinkage porosity and high uniform mechanical properties were obtained in ingots which were poured *at the slowest rate* which would fill the mold completely without cold shuts. This minimum rate was related to ingot size and shape by the formula

$$R = KP,$$

where R is the pouring rate, P is the periphery of ingot cross section and K is a constant. A single central stream giving this critical rate was most satisfactory with square sections or with strip ingots up to 6 in. wide; with wider ingots, two slower streams totaling the required critical rate gave the best results.

The other variables were found to have only a minor effect on soundness, but they controlled the surface quality of the ingot. For good clean surfaces the mold had to be lined or sprayed very lightly with a combustible dressing, and the stream so controlled as not to strike the mold wall.

Ingots containing up to 14% of tin, produced from degassed metal under these conditions, could be rolled hot or cold after suitable annealing to remove the δ phase. This technique was successfully applied in industrial practice. One example was an aircraft bearing cage which required exceptionally high fatigue strength, with good bearing properties. All other materials had failed but a 12% tin bronze which was made by this technique was successful.

In the course of these investigations on strip ingots it was noticed that, with certain molds and casting conditions, a band of tin sweat was formed on the faces of the ingots. Following this observation, a detailed examination for segregation was made. The 10% tin bronze strip ingots were found to exhibit typical inverse segregation, irrespective of whether the surface showed the sudden increase of tin content associated with the presence of the compound layer.

*Detailed results of these studies have been published by W. T. Pell-Walpole and V. Kondic in *Journal* of the Institute of Metals, V. 70 (1944), p. 275, and in *Metallurgia*, 1946.

New Theory of Inverse Segregation

Segregation in these ingots cannot be accounted for satisfactorily by any of the old theories, since solidification proceeds continuously with pouring and no cavities are formed either as a result of gas evolution or of contraction on solidification. The variations in composition can, however, be accounted for by considering the mechanism of solidification in such an ingot.

A slow pouring rate with very little turbulence insures a shallow liquid head and a shallow pasty zone. Solidification proceeds by the inward and upward displacement of this zone. Now, the zone may at any time be considered as consisting of two regions, as indicated in Fig. 6. In the hotter region are crystals entirely surrounded by liquid. In the cooler region the crystals form a dendritic skeleton. In the hotter region the contraction due to solidification can be compensated for by mass movement of the liquid. In the cooler region the

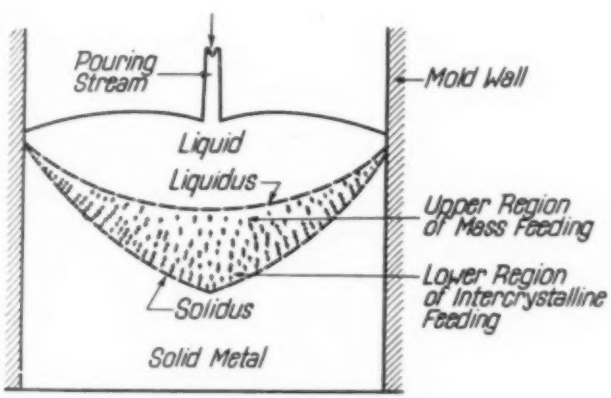


Fig. 6 — Diagram Illustrating the Mechanism of Solidification in a Slowly Poured Ingot

crystals are in contact, and the contraction caused by the solidification of the intercrystalline liquid can only be compensated for by an outflow of liquid from the hotter region along the crystal interstices. The movement of this liquid must deplete the tin content in the hotter region and, as it moves outward along the crystal interstices through a falling temperature gradient, it must deposit a solid of increasing tin content.

As the temperature falls and completion of solidification progresses inward, the depleted inner region in turn receives a feed liquid of high tin content. This process goes on continuously as the pasty zone is displaced inward and upward until the whole ingot is solid.

Thus, at any region in the interior of the ingot the tin content is depleted during the early stages of solidification and increased as solidification in the region becomes completed. The final composition at any point will be determined by the balance of these two effects: *(a)* No depletion occurs in the surface layer; elsewhere this effect should be constant throughout the ingot. *(b)* The total amount of feed liquid received by any layer should not vary, but its average composition will decrease in tin content in proportion to its distance from the outer surface.

At the surface, cooling is most rapid and a considerable amount of β is formed, due to slowness of diffusion. Solidification of this β causes an inflow of feed liquid of peritectic composition, since the temperature must be 800° C. (1475° F.), the temperature at which β forms. Proceeding from the surface inward, temperature gradients become flatter, diffusion occurs more readily, and when crystals reach the stage at which intercrystalline feeding occurs the intercrystalline liquid has a lower tin content. Hence, when it solidifies, the contraction is fed by a liquid of lower tin content than that which fed the surface layers. Thus, after completion of solidification there is a gradual decrease of tin content from surface to center of ingot, but no undesirable cavities are present.

Tin Sweat — With this conception of the mechanism of solidification it is possible to see how a local surface layer of tin sweat can be formed. If, during freezing, a gap occurs between the solidified crust of the ingot and the mold walls (for example, by warping of the latter, or by burning away of mold dressing), then this gap will be fed, as it forms, by intercrystalline liquid percolating through the skeleton ingot already cast. Since the temperature at the mold face must be lower than at any point within the ingot, this feed liquid must have a tin content not lower than that of the peritectic composition. It will therefore solidify as β or as a mixture of β and γ. Such a layer on farther cooling will consist chiefly of the very brittle δ and Cu_3Sn compound, a conclusion that agrees with actual chemical and microscopical analyses of the tin sweat layer.

This conception of the formation of tin sweat in gas-free, slowly poured ingots has been tested in practice. When such tin sweat has occurred, extra precautions to avoid warped molds, as by improved clamping arrangements, have cured it.

Rolling Properties — Ingots containing up to 14% tin cast by these procedures at the critical rate into molds suitably dressed and clamped so as to be rigid during cooling were quite free from porosity or tin sweat; after a short anneal to remove the δ constituent they could be rolled hot or cold without cracking.

The variation of properties with tin content was then examined in the as-cast and in the annealed conditions, and the rolling and annealing characteristics were determined. These findings have been reported by the present author to the Institute of Metals (*Journal*, 1946-I, p. 19).

The working characteristics, both hot and cold, and properties of various ternary bronzes produced by these routines are being investigated at the present time.

Application to Complex Bronzes

Melting — When these alloys were made from virgin melts, the ordinary degassing flux as developed for the binary tin bronzes proved quite satisfactory, provided the copper or copper-tin alloy was degassed first and the other alloying additions were made after removing the flux.

Casting Solid Billets — These alloys are normally cast into cylindrical sticks or billets in cast iron molds. Variation of casting procedure showed again that pouring rate was the most important variable affecting density and properties, and that maximum soundness and highest properties were obtained when the pouring rate was the minimum for filling the mold without cold shuts. The constant rate for a given alloy was again found to be related to the ingot size by the formula derived for the binary tin bronzes, $R = KP$. The value of the constant K, however, varies with alloy composition; it decreases markedly with increasing phosphorus content, decreases slightly with increasing tin or lead content, and increases slightly with increasing zinc content. It is in effect inversely proportional to the effective fluidity of the alloy. When degassed metal was poured at the critical rate for the given ingot size (as shown in Fig. 7), the density was never more than 1% below theoretical, and mechanical properties were approximately 50% above those normally obtained in industry. An investigation of the properties of ternary phosphorus bronzes prepared by these methods has been published by K. Winterton in the *Journal* of the Institute of Metals (V. 71, 1945, p. 581) and some of the results summarized in Fig. 8.

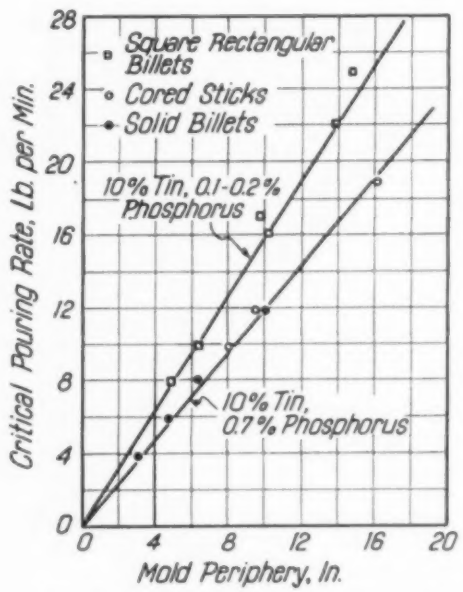


Fig. 7 — Relation Between Size of Solid and Cored Billets and Critical Pouring Rate of Ternary Bronzes

Cored Billets — In attempting to apply the same principles to cored billets, a new difficulty was encountered. Such billets are normally made with a sand core, since a metal core is gripped by the thermal contraction of the solidified casting, and cannot be extracted. This procedure causes three sources of trouble:

1. Shrinkage porosity at core face.
2. Gas absorption from reaction between the bronze and combined water present in the sand.
3. Machining difficulties due to sand burned on to the inner surface of the cored casting.

In an attempt to obtain rapid cooling conditions throughout such a casting and thus eliminate the shrinkage trouble, experiments were made to develop a highly compressible loam coating which could be plastered onto a metal core, giving the necessary allowance for shrinkage of the casting, but chilling the metal from the core as well as from the outer mold.

With this type of core baked at 300° C. (575° F.) to reduce any risk of gas absorption, the effect of casting conditions was investigated, adding the variable of number and position of pouring streams. The same general rule was found to apply as for solid billets, bars and strips — namely, maximum density and properties were obtained when the pouring rate was the minimum consistent with filling. The critical rate varied with ingot size according to the old formula, slightly modified:

$$R = K(P_e + P_i)$$

where P_e and P_i are the external and internal peripheries of the casting. This fits in with the theory for other shapes if $P = P_e + P_i$ is proportional to the total chilling area.

Some variation in properties was found as between positions in a cored stick near to the pouring stream and positions remote from this stream. This variation around the periphery has since been shown to be related to the annealing effect of the "well" of heat near the stream position; consequently least variation obtains with the greatest practical number of feeding streams. Even the best properties were inferior to those from equivalent solid billets, a circumstance that is due to gas absorption from the combined water in the sand.

Investigations to minimize this last mentioned

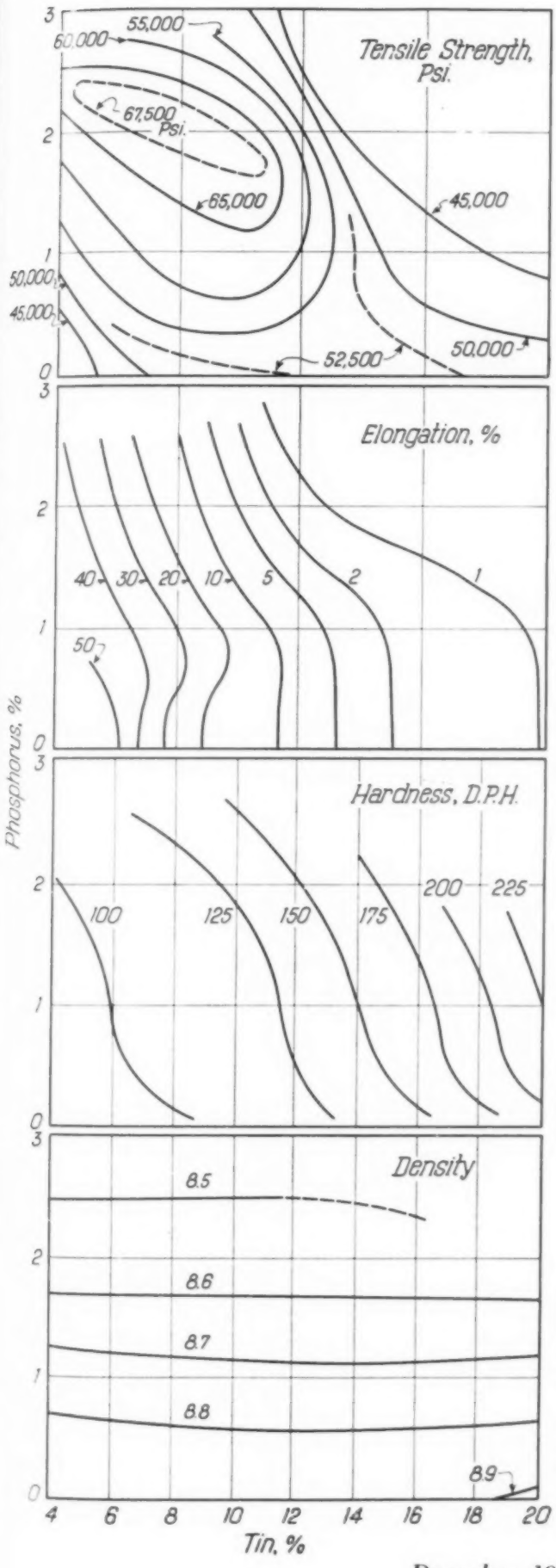


Fig. 8 — Ultimate Tensile Strength, Elongation and Diamond Penetrator Hardness of Phosphorus Bronze Billets, Chill-Cast by the Improved Methods Described in the Text

source of trouble were then carried out, and they were reported in some detail by the present author in *Foundry Trade Journal* for January and February 1946.

Gas absorbed from the sand results from a reaction

$$Me + H_2O \rightleftharpoons MeO + 2H$$

The nascent hydrogen dissolves in the bronze and diffuses throughout the still-molten metal very rapidly. The extent to which this reaction proceeds is governed by three main factors:

1. The concentration of combined water present in the sand's bonding material.
2. The pouring temperature, and the mass of sand involved, which determines the temperature reached at the sand-metal interface.
3. The composition of the bronze.

The water concentration is determined by the nature and quantity of bonding agent, and by the efficiency of baking, as determined by the time, temperature, and degree of air circulation maintained during this operation.

These factors were examined for a great number of sand mixtures containing natural or artificial bonding agents. The mixture to be tested was lined into a pouring nozzle and drilled to give the critical pouring rate for a 2-in. billet, and a melt of degassed bronze was poured through this lined funnel. The density and properties of the resulting billet were compared with those of a similar billet poured from a degassed melt through a clean gray-graphite funnel, not lined.

Bonding agents consisting of linseed oil and cereal were much superior to all other types tested. For a given bond and baking conditions the amount of absorbed gas increases rapidly with increase of pouring temperature; for constant pouring temperature it decreases with increase of baking temperature and with the extent of air circulation. High phosphorus, high tin bronzes absorb gas most readily, zinc bronzes absorb less gas, and the leaded bronzes least.

Cored billets made with a chill core coated with a mixture of sea-sand oil and cereal, baked at 200° C. (400° F.) and poured at the lowest temperature consistent with the use of the slow critical pouring rate, had properties very nearly equal to those of solid sticks. Such results, however, could only be obtained by very close control of the factors concerned.

Asbestos Covered Core — The "nongassing" loam-coated core still left unsolved the difficulty of a rough inner surface. An alternative core was

developed to avoid this, by wrapping asbestos paper around a metal core. This met the requirements for easy extraction and gave excellent inner surfaces, but caused gassing in the same manner as the sand cores, due to the combined water present in the binding agent.

Further experiments showed that by baking such a wrapping at 300° C. (575° F.) and painting the surface with a wash containing 5% of aluminum powder and 2% of dextrine, gassing was inhibited — providing the core was not more than 2 to 3 in. in diameter so that three layers of paper were sufficient to permit extraction. Large diameter cores required some six to eight layers of paper, and this caused a considerable degree of gassing and greatly insulated the chilling effect of the metal core.

Split Core — This indicated that for large bore castings, such as for gear blanks, some alternative form of core was necessary. The solution was found by splitting a cast iron core into quarters, removing $\frac{1}{16}$ in. from each radial face, and inserting a layer of asbestos paper ⅛ in. thick. The paper layer permits the required degree of contraction of the cored casting and, since it is in contact with the molten bronze only at the ⅛-in. edge at each quarter point, it causes no appreciable amount of gassing.

Further development of this idea is in hand.

Ternary Bronzes From Scrap

The position at this stage was that chill castings of any commercial ternary tin bronze in any common size or form of ingot could be prepared so that the material was sensibly free from gas and shrinkage porosity and from tin sweat.

The next problem to be solved was to devise a degassing treatment suitable for ingotted or scrap charges of these alloys.

It is clear that, for such charges containing oxidizable elements, the flux must contain more available oxygen to effect complete degassing, since part of the oxygen is fixed as metallic phosphates, zinc oxide, or other nonmetallic particles.

Standard Metal — Experiments were made with gassed scrap charges to determine the concentration and quantity of flux required for degassing. Metal was prepared to a standard gas content by pouring a degassed virgin melt through a funnel lined with a known weight of molding sand with a fixed water content. By this method a 10% tin bronze with 0.7% phosphorus, a 10% tin bronze with 2%, 88-10-2 gun metal, and 88-5-5-5 red brass could be produced containing 2 to 3% porosity. Leaded bronze was not seriously gassed by this procedure, suggesting that hydrogen is not very soluble in highly leaded bronzes; however, a little hydrogen was introduced, sufficient to produce about 1% gas porosity, by adding molding sand directly to the melt.

Charges of the standard gassed metal of each composition were then melted under oxidizing fluxes of varying CuO contents and poured into chill molds under conditions known to give freedom from shrinkage porosity. The ingots were examined for density, tensile properties and shrinkage. In each series of tests smooth curves were obtained relating density and tensile properties of the ingots to the CuO content of the flux used.

Low-phosphorus bronze and leaded bronzes were completely degassed with the flux containing 33% CuO by weight. High-phosphorus bronzes and gun metals required a rich flux containing 50% CuO. The total amount of flux used had little effect on the results, providing there was sufficient for a fluid seal.

Alloys of low gas content — as the highly leaded bronzes — could also be degassed by melting with an oxidizing flame without cover. This method, however, was useless with high-phosphorus or zinc bronzes.

Commercial Oxidizers — In view of the cost of CuO, cheaper oxides were investigated. Their drawback, even if efficient, is that reduction of the oxide may contaminate the melt. Experiments were made with various concentrations of MnO_2, SnO_2, Pb_3O_4 and Fe_2O_3. The first two were quite efficient. With MnO_2 only 0.002% Mn was introduced into the metal. Reduction of tin from SnO_2 was of course beneficial rather than a source of trouble, but this reagent is even more costly than copper oxide. Pb_3O_4 and Fe_2O_3 were inefficient and uncertain in degassing action and caused serious contamination of the melt. Other oxides have yet to be tried.

An alternative method of cheapening the flux was to use commercial forms of copper oxide such as copper mill scale. Scale from hot or cold rolling mills was quite efficient at a concentration of 50%, but certain supplies of so-called mill scale failed. Tests showed that they were contaminated with hydrated copper salts from pickling vat residues. These salts introduced a serious amount of com-

bined water which reacted with the melt and induced a high gas content. This trouble was eliminated by melting such fluxes prior to use.

Surface Quality in Bronze Ingots

Once practical and economical methods had been established for obtaining consistent freedom from internal defects in any tin bronze, irrespective of composition, size, or shape of ingot, attention was turned to surface quality. In practice this is of considerable importance, particularly in ingots for rolling.

During the researches on gas and shrinkage effects, observations were made on the effect of the variables studied on surface quality. An appraisal of the data at hand indicated that the chief surface defects which have to be considered are:

1. Tin sweat.
2. Blowing porosity (gases mechanically entrapped between ingot surface and mold wall).
3. Cold shuts.
4. Surface inclusions, either of oxide skins or mold dressing.

These defects are primarily determined by metal and mold conditions, but may be modified and controlled by suitable mold dressing.

Cold shuts, splashes, and oxide traps are avoided by the controlled pouring process. Blowing is also reduced similarly, but even then occurs if the metal stream impinges on the cast iron mold wall, since normal dressings are washed off under these conditions. If washes are thick enough to stand scour, tin sweat results from gas absorption.

G. L. Bailey's theory of blowing, advanced in *Journal* of the Institute of Metals (V. 49, 1932, p. 203) is that it is caused by a reaction between iron scale and carbon of the cast iron mold when locally heated, generating carbon oxides which become entrapped. Observations during our researches suggested that the oxide involved was that on the metal surface rather than on the mold. Thus, blowing occurred most readily in highly fluid phosphorus bronzes and leaded phosphorus bronzes, less in gun metals and oxidized tin bronzes, and was not observed at all when aluminum was present in the metal.

The degree of inhibition provided by the oxides present may be due to *(a)* mechanical or thermal insulation of mold, or *(b)* differing reactivity of the oxide with carbon. Whichever of these is correct, the observations suggested that if Al_2O_3, or a similar nonreactive oxide, were applied to the mold's surface with a sufficiently strong carrier, blowing might be prevented. Suspensions of Al_2O_3 and of aluminum powder in various carriers were then tested in comparison with ordinary dressings.

Blowing was completely prevented, even under unfavorable conditions, with a suspension of aluminum powder in a heat-hardening synthetic resin. This dressing, which can be applied thinly enough to avoid gas absorption or carbon traps, gave ingots which could be rolled directly to give flaw-free strip and other shapes.*

Continuous Casting

This work on surface quality completed the researches on static methods of casting, and the procedures developed left only one disadvantage: Since turbulence increases with the depth to which the metal stream falls, there is slight variation of properties from bottom to top of a long ingot.

To surmount this difficulty, an experimental plant for semicontinuous casting with a water-cooled copper die, incorporating the methods of degassing and slow pouring, was developed with considerable success. Bars of 1 to 2-in. diameter up to 3 ft. long were made. They had quite uniform properties throughout their length and were slightly superior and more consistent than the best obtained with static molds.

Impurities

The work summarized in this article is now being extended to cover the effects of impurities on casting characteristics and on properties. So far, aluminum and bismuth are shown to be most harmful, while arsenic, antimony, iron, manganese and silicon are much less harmful in these sound ingots than when porosity is present (as with the older methods of casting). The control of impurities is an important problem from the practical point of view, and present research is directed on finding the extent to which such "impurities" can be eliminated or reduced to negligible proportions by use of fluxes.

It has already been shown that phosphorus, a common impurity in scrap gun metal due to contamination with phosphor bronze, can be controlled quantitatively by the use of oxidizing fluxes. The amount absorbed by a flux is a constant proportion of that present in the metal. This proportion varies linearly with the available oxygen content of the flux. As much as 0.3% of phosphorus can be reduced to 0.05%, an acceptable figure for high quality gun metals. Similarly zinc can be removed from phosphor bronze, and aluminum and iron from all tin-containing bronzes.

*A more complete discussion of the problem of surface quality has been presented by the present writer in a recent article in *Metal Industry* (London).

By G. W. Birdsall
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Reclamation of Aircraft Aluminum

PRACTICALLY all attempts to reclaim aluminum from wrecked and obsolete aircraft have been commercial failures in America because of the cost of preparation and segregation, the comparatively low grade of metal obtained, and the amount of aluminum lost in the dross and slag. Perhaps the most successful practice outside of Reynolds plants was that developed by the U. S. Navy, which consumed 6000 tons of aircraft scrap at six Naval Air Stations in 1945. However, even with metallurgical technique, Navy ingot produced from aircraft scrap averages around 1% iron, 4 to 5% copper, 1% magnesium, and corresponding high amounts of other metals, unwanted in all but the lowest grade casting ingot. Navy practice is to melt the scrap in an open pot, or in a sloping hearth reverberatory furnace, or one of the latter with a metal-holding bath to produce heats of known analyses. (The practice is described generally in *Modern Metals* for April 1946, page 8.)

However, a number of difficulties are involved. Pot melting requires that metallic parts or alloys containing lead, iron, magnesium and zinc be removed almost completely from the aluminum scrap before melting. Since this (and the relatively small pot sizes) necessitates cutting up the aircraft and involves a large amount of laborious hand work in removing all sorts of fittings like copper wiring, steel control cables, wing hinge forgings, armor plate, firewalls, brass fittings, and bronze bushings, this segregation is very costly.

Pot melting picks up an excessive amount of iron, due to its ready solubility in molten aluminum. Melting on a sloping hearth (wherein the fusible metals drain away quickly from the unmelted iron and copper alloys) has involved considerable loss by oxidation; in fact, some engineers simply say you cannot melt thin aluminum scrap "in the air".

Again, the percentage of undesired elements reported in the recoveries is still greatly above that specified in ingot for wrought or cast products. (See Tables I and III for typical values.) Thus, this reclaimed metal must be remelted and sweetened with virgin or high purity aluminum to bring the analysis within the range desired.

Regardless of the type of furnace, charging it with aircraft scrap has involved much expense because such material is bulky and difficult to handle, often with sharp, ragged edges. The cost of cutting up the scrap to size convenient for charging, combined with the cost of separating out copper, brass, steel, and other nonaluminum alloys, made the operation seldom profitable — especially since the aluminum ingot obtained was of a comparatively low grade and the proportion of metal recovered was low.

It is interesting to see how these factors were overcome at Reynolds Louisville Plant No. 5 (Reclamation) where Norman Kohlhepp, the plant manager, and his assistants C. W. Briel, J. E. Bramblette, and R. Van Winkle, developed some very definite ideas concerning reclamation methods, have kept the costs well in line and — what is most important — the reclaimed metal is of such purity that no sweetening is required to make it suitable for use in wrought or cast products conforming to present-day specifications.

These men started to reclaim wrecked aircraft with considerable experience gained from the recovery of more than 5,000,000 lb. of aluminum per month during the war. Reynolds plants were required to experiment with aluminum scrap of all types to the end that it could be refined and used in good sheet that would meet aircraft requirements. With the quality standards thus set high, Plant No. 5 started using only a small amount (about 20%) of scrap, mixing it with virgin aluminum. Within eight months, charges were made up of 100% scrap, with resulting metal

meeting the original standards of the sheet from which the scrap originated. Some 100 cars of aircraft scrap were being handled monthly.

Furnace practice was worked out during this period to a point where even sheet 0.020 in. thick is remelted with a recovery of 96 to 98%. Since 2% can easily be lost in fluxing operations, this means that no metal is lost from burning during the melting operation. These results contrast greatly with the opinion of many experts that it is not feasible to melt light aluminum scrap except by immersing it in a metal bath.

This ability to remelt thin sheets is essential if wrecked aircraft is to be successfully reclaimed. It is also evident that the greater the percentage of aluminum recovered, the better the operation is from a dollars-and-cents standpoint.

Complete recovery of the fusible yet oxidizable aluminum comes about through the use of a reducing flame at all times. The sloping or sweating hearth type of melting furnaces employed at Plant No. 5 use two 6-in. Hauck oil burners, one firing crosswise the 15-ft. long sloping hearth just inside the 8x8-ft. charging door, the other firing lengthwise about 3 ft. above the molten metal in the 8-ft. square holding hearth at the opposite end of the furnace.

A reducing flame is obtained by supplying an excess of oil, easily noted in the furnace as a slight swirling mist or vapor. Furnace atmosphere leaking out and burning around doors also indicates a reducing atmosphere within. In such an atmosphere there is always excess oil ready to unite with any oxygen that enters during charging or drossing operations, or through any crevice. The melting aluminum is thus protected so it does not burn up in the furnace atmosphere.

Preparation costs are negligible at Plant No. 5 because refining methods take care of any tramp metals that may be mixed in with the aluminum scrap. No parts less than 8 ft. wide are cut up. Even complete wing and fuselage sections are melted without cutting; in fact, full wing and fuselage sections are preferred.

Iron or brass parts do not melt in the furnace and are removed from the sloping hearth by raking out through side doors (Fig. 4, page 1236). The only work done on incoming metal is precautionary in nature, such as dynamiting fuel tanks to remove the possibility that gasoline vapors locked in structures, tanks or connecting lines may explode when put into the hot furnace.

Furnaces have 8-ft. square openings for charging — some are 9-ft. square — which adapt them for mechanical handling equipment and entirely eliminate costly hand charging methods. Accompanying illustrations demonstrate the two systems utilized.

New furnaces on the main floor are charged directly from gondola cars by means of a rubber-tired crane operating up and down the charging floor (Fig. 1). A clamshell

Process Innovations in Brief

Conventional Practice	Reynolds Practice
Cuts up scrap into small sections for charging.	No cutting; charges complete fuselage and wing sections if these are encountered.
Segregates lead, copper, iron, brass, and other alloys by hand.	Does not segregate anything by hand; melting practice takes care of impurities.
Charges small pieces, largely by hand.	Charges everything mechanically in large batches.
Uses granular fluxing materials such as aluminum chloride charged under bath surface by hand. Fluxes at intervals.	Uses chlorine gas exclusively for fluxing. Fluxes continuously.
Considerable metal lost by burning in the furnace. Much dross and skimmings produced.	Little metal lost by burning; over 95% recovery of aluminum content.
Poor quality metal, high in undesirable elements, which requires sweetening with virgin metal before use.	Excellent quality metal, good for foundry castings, forge or rolling mill ingots by simple remelting additions.

Table I
Analysis of Navy Reclaimed Ingot*

Element	Class A	Class B	Class C
Copper	4.50	3.50†	6.50
Iron	0.60	0.75	1.10
Magnesium	1.00	1.50	1.50
Manganese	0.50	0.65	0.65
Nickel	0.10	0.10	0.25
Silicon	0.50	0.50	1.00
Tin	0.10	0.10	0.15
Zinc	0.20	0.25	1.00
Lead	0.07	0.10	0.50
Chromium	0.10	0.10	0.10
Titanium	0.10	0.10	0.10

*From *Modern Metals*, April 1946, page 9. Another class (Class D) makes up the remainder of the ingot produced by the Navy according to the following policy: When an activity is faced with a run of uniform, segregated material such as 3S fuel tanks and aircraft engine cylinders (high nickel), the metal will be stockpiled and properly identified; individual analytical records on heats of the Class D ingot will be available.

†Includes a range from 3.50 to 5.00.

Fig. 1 (Above) — Charging Floor in New Addition to Plant No. 5 Containing Six New Sloping Hearth Furnaces. Portable crane travels up and down charging floor between furnaces and gondola cars. Scrap is picked up by clamshell bucket, swung over and dropped on elevated charging platform

bucket lifts the scrap from the gondola, the boom swings around toward the furnace and drops its load on the elevated charging platform which is level with the sloping hearth inside the furnace.

When enough metal has been placed on this charging platform, the furnace door lifts and the entire charge is pushed into the furnace by a fork truck and ram (Fig. 2). This welded steel ram has hollow slots in its base, into which the forks of the truck fit; the truck lifts the ram and maneuvers it to the end of the charging bin, and pushes the charge into the furnace as it moves forward, like a bulldozer.

Those furnaces located too far from the railroad siding to permit charging directly as described above are fed by large bins carried by a fork truck. These bins are loaded near the gondola by a crane. The truck then carries the bin to a furnace and elevates the bin above the charging platform. A special revolving head carrying the forks then turns

Table II — Typical Cast Analyses at Reynolds Louisville Plant No. 5

Element	Average★	As Low As†
Iron	0.45	0.30
Copper	4.25	3.80
Magnesium	0.25	Trace
Manganese	0.55	0.45
Chromium	0.01	Trace
Zinc	0.15	0.03
Lead	0.25	Trace
Titanium	0.01	Trace
Nickel	0.01	Trace

★Averages of about 200 successive furnace melt analyses.

†"As low as" values are from same series of analyses.

Fig. 2 (Below) — Fork Truck Picks up a Large Ram and Uses It to Push the Charge Into the Furnace. Charging platform is on rollers. When charging, the ram is used first to push the platform so its floor and sides extend into the door, thereby assuring that all scrap clears the doorway

the bin over (Fig. 3). The load is then pushed into furnace by the fork truck with the ram, as already shown in Fig. 2.

Vertical lift doors expose openings for charging measuring 8x8 ft.; new furnaces now going in will be 9x9 ft. These large openings accommodate rough scrap as it comes, without need for cutting. Entire wings and fuselages, 30 ft. or more in length, are also melted down without cutting in the following manner: The fuselage is placed in the furnace as far as possible with the crane, the furnace opening is closed with a chain curtain and the metal inside melted. The remainder of the chunk is then pushed in and melted; perhaps three such stages may be required.

molten aluminum, effectively fluxing out impurities. In fact, analyses ranges shown in Table II reveal that magnesium can be reduced greatly where magnesium is not wanted. Compare these with the ranges shown in Table I, produced by pot melting without gas fluxing.

Chlorine is run direct from tank cars to the furnaces in the system sketched in Fig. 5 that was designed and built at Plant No. 5 in cooperation with Pennsylvania Salt Mfg. Co. Six furnaces use about a tank car of chlorine each week. A rather full description of this installation may be of interest since it represents developments that have now been adopted by other Reynolds plants, and no similar ones were in existence when this was made.

Table III — 17S and 24S Compositions

Specification	Alloy	Desired Alloying Elements			Definite Impurities (Max.)				Other Impurities (Max.)	
		Cu	Mn	Mg	Fe	Si	Zn	Cr	Each	Total
Navy 47A3c	17S	3.5 to 4.5	0.4 to 1.0	0.2 to 0.75	1.0	0.75	0.03	0.25	0.03	0.1
Federal QQ-A-361	17S*	3.5 to 4.5	0.4 to 1.0	0.2 to 0.8	1.0	0.8	0.03	0.25	0.03	0.1
A.M.S. 4032B	17S	3.5 to 4.5	0.4 to 1.0	0.2 to 0.8	1.0	0.8	0.1	0.25†	0.05	0.15
A.S.T.M. B78-44T	17S	3.5 to 4.5	0.4 to 1.0	0.2 to 0.8	1.0	0.8	0.1	0.25	0.05	0.15
A.S.T.M. B89-44T	17S	3.5 to 4.5	0.4 to 1.0	0.2 to 0.8	1.0	0.8	0.1	0.25	0.05	0.15
Navy 47A10e	24S	3.8 to 4.9	0.3 to 0.9	1.2 to 1.8	0.5	0.5	0.1	0.25	0.03	0.1
Federal QQ-A-355a	24S	3.8 to 4.9	0.3 to 0.9	1.2 to 1.8	0.5	0.5	0.1	0.25	0.03	0.1
Federal QQ-A-362	24S*	3.8 to 4.9	0.3 to 0.9	1.2 to 1.8	0.5	0.5	0.03	0.25	0.03	0.1
A.M.S. 4037A	24S	3.8 to 4.9	0.3 to 0.9	1.2 to 1.8	0.5	0.5	0.1	0.25	0.05	0.15
A.M.S. 4041A	24S*	3.8 to 4.9	0.3 to 0.9	1.2 to 1.8	0.5	0.5	0.1	0.25	0.05	0.15

*Clad. †Also 0.15 max. titanium.

Each furnace is charged just as often and just as fast as possible, the aim being to get a continuous melting operation. Molten metal is tapped off in 5000-lb. lots (Fig. 6, page 1237), about half the content of the holding hearth. Fluxing is continuous.

Chlorine Gas Fluxing

Iron content in the reclaimed aluminum is kept low because molten aluminum is not allowed to remain in contact with any hot steel. As soon as the aluminum melts, it runs off the iron or steel parts, down the sloping hearth and into the holding hearth or basin, so there is little opportunity for iron pickup. Then chlorine gas, the only fluxing agent used, is bubbled into the bath of

Fig. 3 — In the Older Portion of Plant No. 5, Where There Is Not Sufficient Room Overhead to Swing the Crane Boom, the Loading Platforms at the Furnaces Are Charged by a Unique Revolving Head on a Lift Truck, Which Has Carried the Bin Loaded With Scrap

Traces of chlorine gas in the air can be extremely irritating to humans and for that reason there was some hesitancy in using it in commercial furnaces. However, sound engineering of handling equipment and safety practices have proven highly effective and no trouble has been encountered.

As shown in the diagram at right, above, liquid chlorine arrives at the plant in insulated tank cars of 30-ton capacity under a pressure of 80 to 90 psi. The top of the tank car has four valves, two being gas or blow-off valves venting the very top of the tank, and two connecting to lines ending near its bottom. These two are used for drawing off the liquid chlorine. Connection is not made to either of the gas valves because withdrawal of gaseous chlorine would quickly reduce the tank car pressure and make unloading of the car contents very difficult.

A railway siding used exclusively for chlorine cars and provided with a locked switch and derail accommodates two tank cars so when one empties, another is at hand for immediate use. The 200-ft. line from tank cars to evaporator unit is fabricated from 1-in. extra heavy steel pipe with welded joints. It is buried underground. A tank car connects to this line through a 10-ft. length of flexible high-pressure copper tubing, a valve, a pressure gage, and a line valve.

Connections at evaporator and in lines to furnaces are made with ammonia type, two-bolt tongue-and-groove flanged unions with lead gaskets. Fittings are forged steel, rated at 600 lb. Furnace flow control valves are ¾-in. standard Chlorine Institute ton container type. Main line cutoff valves are Crane No. 1644. Gages are of the protected type with silver diaphragm.

Vapor pressure from the chlorine in the tank car is above critical pressure for liquefaction, and maintains the line at 70 to 90 psi. which is more than ample to force the liquid through the piping system and to inject it into the molten metal bath. A final complete drop in pressure at the gage alongside the tank car shows when the tank is empty. Inventory records of reclaimed metal provide a weight check on quantity of chlorine used. The evaporator is on the main furnace floor in a small booth to one side of the furnaces. It is at approximately the same elevation as the tank car.

The evaporator consists of a 5-ft. length of 8-in. diameter extra heavy seamless steel tubing mounted inside a 3-ft. length of 14-in. tubing, to make a 3-in. water jacket between the two. A heavy tongue-and-grooved blank flange is fitted to the bottom of the 8-in. tubing to facilitate inspection and cleaning. A rupture disk is connected at the top as a safety, this being a 2-in. diameter silver disk rated to blow at 225 psi. The space between the two lengths of tubing has water pumped through it continuously from a 50-gal. tank alongside; this water is maintained at 150° F. by four 6-kw. immersion type electric strip heaters installed in the 50-gal. tank. Current is controlled by thermostat, and a makeup device automatically maintains the water level.

As heat is supplied to the liquid chlorine flowing into the bottom of the 8-in. tubing, it evaporates and flows out into the furnace line at a pressure of 60 to 70 psi. Evaporator, water heater and all gas lines are carefully insulated with a ⅞-in. coating of 85% magnesia.

From the manifold at each furnace, flexible hose connections carry the gas to the discharge tubes which reach to the bottom of the metal bath. The strong stirring action that results as the gas bubbles up to the top is important. It eliminates the need for mechanical stirring. Discharge tubes are of nonmetallic material (to prevent iron or other alloy pickup), coated with a refractory, through which the gas is finely dispersed.

Fig. 4 — Operator at Extreme Rear Is Pulling Steel and Other Refractory Materials Off the Sloping Hearth. Aluminum has melted and run down into the bath at right. Operator in foreground is skimming off dross from top of bath, pulling it into the dross buggy

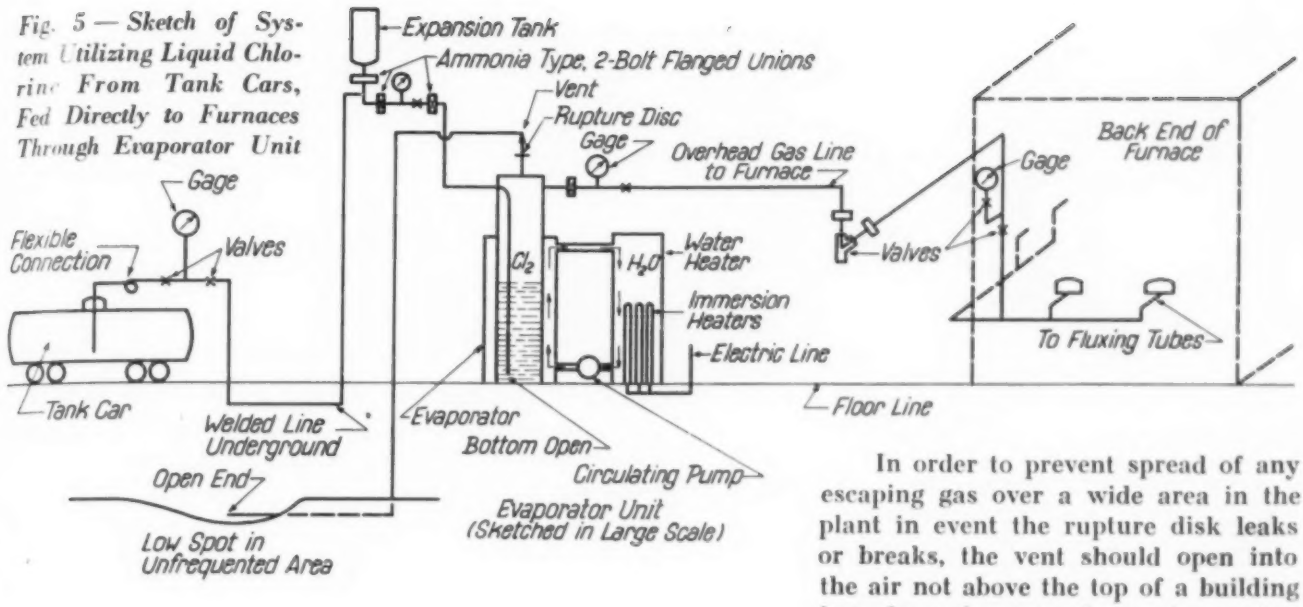


Fig. 5 — Sketch of System Utilizing Liquid Chlorine From Tank Cars, Fed Directly to Furnaces Through Evaporator Unit

Safety Measures

Chlorine gas is toxic if inhaled in quantity. It also can cause serious internal corrosion in pipe lines if moisture is allowed to enter. However, this gas has caused no serious trouble.

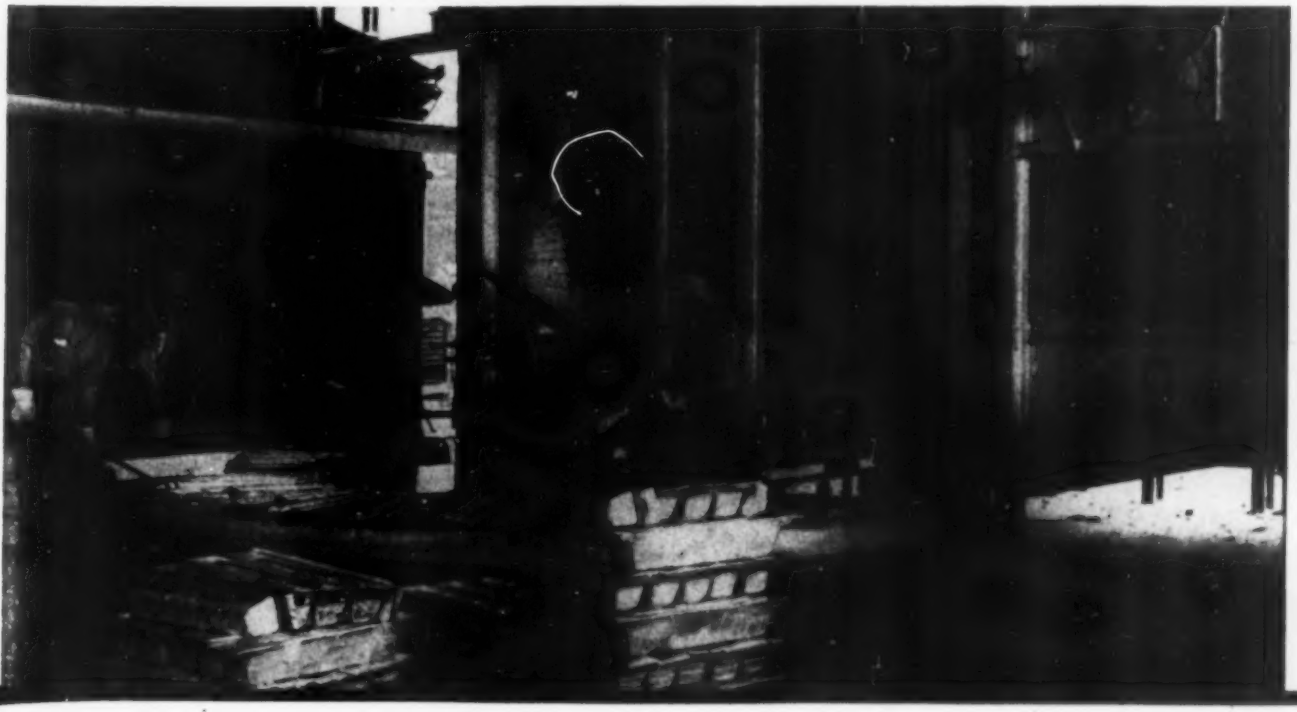
Safety measures built into the system include an expansion tank mounted inside at the highest point on the unloading line (see diagram). This tank is an empty 100-lb. cylinder for liquid chlorine, mounted vertically, upside down, and is of sufficient volume to absorb any expansion in the system. Another safety measure is the frangible diaphragm in the top of the evaporator, designed to rupture at 225 psi. The discharge side of this safety head is connected to a vent to carry away the gas to a safe point if the disk blows out.

In order to prevent spread of any escaping gas over a wide area in the plant in event the rupture disk leaks or breaks, the vent should open into the air not above the top of a building but along the ground at a low point. Since chlorine gas is heavier than air, gas would be simply poured on the building if an overhead vent were to go into operation. It is therefore desirable to have any discharge collect in a low area and not spread.

Rule: Run all vent outlets to a low point on the ground, and inspect the open end of the vent frequently to check the tightness of the diaphragm.

It is important to insulate the gas lines properly, or condensation will liquefy the chlorine and form slugs or blobs that may enter the bath. Furthermore, liquid chlorine rapidly attacks rubber hose connections. Placing pipe lines high and away from mechanical damage is also an absolute essential. Sufficient valves should be employed to permit the isolation of any furnace or section without shutting down the entire system. Gas

Fig. 6 — Casting Ingots of Reclaimed Aluminum From Sloping Hearth Furnace. Note piping to oil burner at upper right, and inclined chlorine feed tube through small arch in furnace wall near left corner



masks are kept handy for use in repairing leaks.

When working on lines that have been used to carry chlorine gas, be sure to cork up all openings in the system to prevent formation of hydrochloric acid by reaction with moisture in the air. Remember that chlorine will not attack iron or steel pipe if it is kept *dry* and at temperatures below 180° F. (Higher temperatures result in rapid attack.)

What would happen if some gas condensed in the lines and liquid chlorine entered the bath of molten aluminum — an explosion? No. This proved to be a needless worry because even then the chlorine is vaporized in passing through the feed tubes and simply produces a few extra large bubbles of gas as it escapes up through the bath.

Confirming the experience of other large users of chlorine gas in the chemical process industries, Reynolds has found its use to involve no serious health hazard.

Comparing Tables II and III, it will be noted that the reclaimed aluminum lacks nothing in quality. Note particularly that no desirable alloying elements are lost in reclamation. There are some pickups in lead and zinc; casts high in these elements may be segregated for dilution with purer metal or other appropriate disposition.

The values given in the table are not picked but represent actual figures from several pages of reports. They illustrate that magnesium, a troublesome element, can be held to from 0.25% to a mere trace, when desired.

By referring to Table III, it is evident that such reclaimed metal can easily be remelted and brought to definite desired composition ranges such as those for 17S or 24S simply by the addition of alloying elements. Sweetening with virgin aluminum is seldom required to make good metal for foundry, rolling mill or forge shop.

German Methods of Recovery and Refining*

Little attempt was made in Germany to reclaim aluminum until late in the war, for no shortage in commercial ingot existed until then. The plants investigated by British and American metallurgists therefore appeared to be improvisations, for the most part. While rules for segregating scrap were established, it was evident they were not followed properly. Likewise no account was taken of such facts as that engine scrap was quite different in its nature if derived from British, American or German wrecks.

Melting was done on inclined hearths, sloping 1 in 6 to 1 in 12, and usually about 6x12 ft. in area. (In one plant the hearth consisted of cast iron grate bars, through which the molten metal trickled.) Most furnaces had two holding hearths, separated from the melting hearth by weir wells to prevent entrance of unmelted matter. Arrangements were made so one pool was filling while the other was being skimmed and cast.

Charging arrangements were rather crude and depended on hand labor. One design had a charging floor about 10 ft. above the melting hearth, wherefrom the scrap was thrown into what was in effect a large bin, down which it settled as it was melted or raked aside at the hearth level. Another charged through a large circular hole in the roof, 9 ft. above hearth level, covered with a dome; when charging, the dome was lifted and trundled aside by an overhead hoist and trolley.

In all such furnaces, the unmelted refractory metals were raked out the side door by hand.

The ingots so produced were off grade as to analysis, and badly contaminated by dross and oxide, so the problem of refining was one of great importance. Of the three methods used for eliminating unwanted metals from reclaimed ingots, the so-called Beck process was the only one that produced sizable tonnages. It was adapted from a scheme intended to purify low grade aluminum (high in iron, silicon and titanium) produced by thermal reduction: Reclaimed scrap was melted with enough magnesium to bring its content up to 30%, the melt cooled to within the mushy range, and held steady while intermetallic compounds of iron, silicon and manganese crystallized out. This suspension of crystals was then transferred hot to a bed of crushed basalt and filtered. Next, the zinc and magnesium in the filtrate were distilled off (under hydrogen at pressure). The residual molten aluminum contained all the copper and nickel of the original charge, and in practice the Beck process was utilized only for about one-third of the scrap ingot produced at a given center, the remainder being mixed with the "purified" material to bring its contents of iron and silicon within engineering specifications.

A little impure ingot was being refined in the three-layer cell used to produce 99.99+ ingot by re-electrolysis of commercial ingot. The drawback of this scheme was that the impurities built up in the bottom layer at too high a rate, and that the magnesium in the metal being refined passed rapidly into the intermediate electrolyte layer and contaminated it beyond endurance.

The third process by which a little aluminum was purified seemed to be one that would involve the maximum of production difficulties. Impure aluminum was amalgamated with mercury at 1100° F., the solid residue (iron, silicon, and titanium and their compounds) filtered out, and aluminum recovered from the amalgam by distilling off the mercury. Post-heating of the aluminum at 1300° F. removed mercury down to spectroscopic traces. By this process iron, manganese, silicon, titanium and nickel were almost completely eliminated; magnesium, tin, lead and zinc were partly eliminated; but copper was untouched. The process required apparatus that was pressure-tight to prevent escape of mercury and also so devised as to exclude absolutely all oxygen during the filtering and distillation stages — obviously quite difficult requirements to meet.

*From reports made by the Combined Intelligence Objectives Subcommittee investigating German industry, summarized in *Metal Industry* for September 13 and 20, 1946.

HANNIBAL'S FROZEN ASSET

The Romans smugly thought the icy barrier of the Alps impassable. But Hannibal turned the paralyzing cold to his advantage. He had water poured into the crevices of road-blocking boulders. The expansion of the freezing water "made little ones out of big ones"—and another road led to Rome.

Low temperature, which worked to Hannibal's advantage, is a distinct disadvantage to operating machinery. Under low temperature conditions, some steels that may perform perfectly at ordinary temperatures, develop unsuspected weakness. There is always danger of a parts failure under such conditions.

One way to assure good performance at low temperatures is to specify molybdenum steels. Good hardenability plus freedom from temper brittleness give them good low temperature impact strength. They are a precaution it pays not to ignore. Practical working data are available on request.

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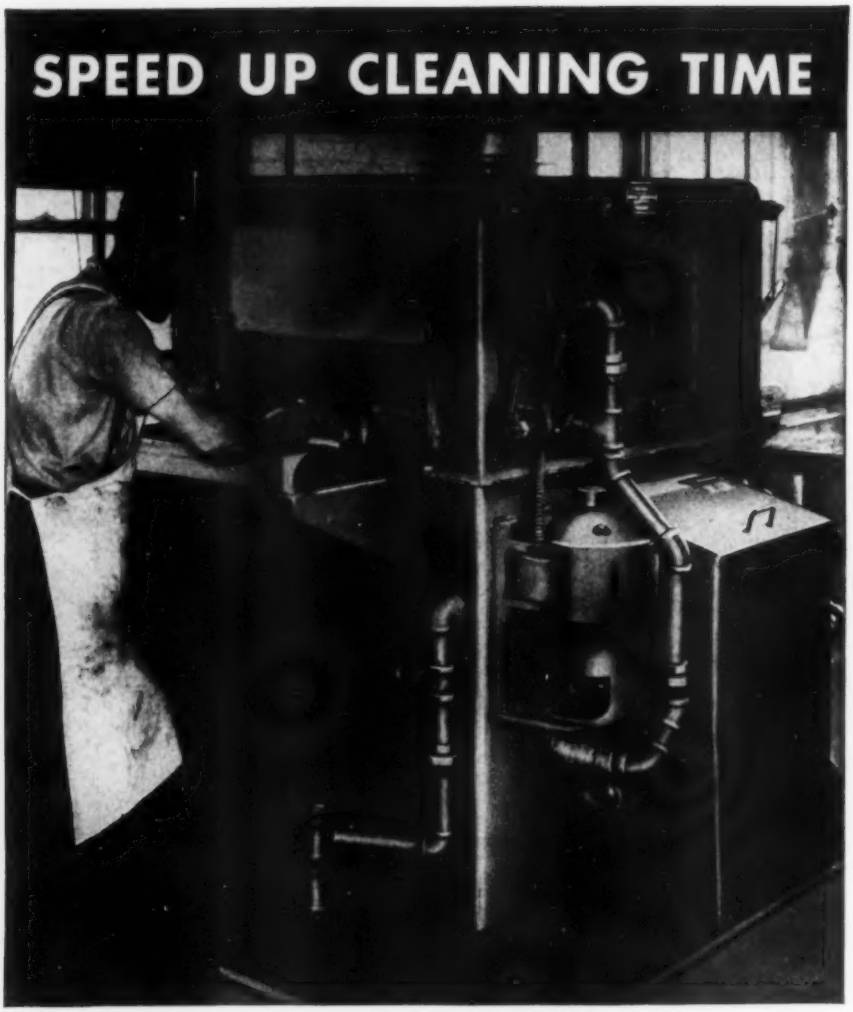

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Personals

LIEUT. COMDR. JACK I. MEDOFF, recently returned from the Pacific, is now on terminal leave from the Navy. He was formerly employed by Worthington Pump and Machinery Corp. at the Holyoke Plant Ordnance Division as metallurgist and chief radiographer.

BLAKE D. MILLS, JR., has been released from active duty in the Navy, where he served as chief of the gun design subsection with the rank of commander, and has been appointed as associate professor of mechanical engineering at the University of Washington.

RICHARD J. TATOUSEK has been placed on inactive duty in the U. S. Naval Reserve and is now associated with the metallurgical department of the Inland Steel Co., East Chicago, Ind., as a metallurgical inspector.

CHARLES O. HERB, associate editor and managing editor of *Machinery* for 27 years, has been appointed editor, replacing ERIK OBERG, who has retired after 40 years on the editorial staff.

JOHN M. PARKS, for the past year editor of technical books for the American Society for Metals, has resigned to become supervisor of welding research at Armour Research Foundation, Chicago.

ROBERT M. PARKE, formerly director of metallurgical research of the Climax Molybdenum Co., has been appointed division engineer in charge of metallurgical research, and will be assigned to the research unit of the Johns Hopkins University, applied physics laboratory, Silver Spring, Md.

ROBERT R. RAWSTRON has been appointed manager at the Delisle Machine Co., New Hartford, Conn. He was formerly with the Norton Co. and Worcester Taper Pin Co. of Worcester, Mass.

ARCHIE L. WALTERS has joined the staff of Battelle Institute and will be engaged in research in the steel processing division. He was formerly metallurgist with International Harvester Co., Springfield, Ohio.

J. M. G. FULLMAN has retired as general design engineer of National Electric Products Corp. after 33 years of service, with more than a third of this time as works manager of the Ambridge, Pa., plant.

DREVER

VERTICAL STRIP ANNEALING FURNACES

Drever Vertical Strip Furnaces. The furnace on the left handles three 8" strips up to five 5" strips, in gauges from .005" to .050" of non-ferrous materials. The new furnace on the right accommodates seven 5" strips up to three 12" strips. Note the bright, shiny finish of the stock coming off the recoiler ready for shipment.

Greatly INCREASE PRODUCTION IMPROVE QUALITY

Versatility and Flexibility of Production—Ferrous and Non-ferrous strip annealed in wide range of gauges . . . Minimum cycle adjustments . . . Rush and trial orders processed quickly . . . Single or multiple strips . . . Capacity from pounds to tons per hour.

High Quality Bright or Open Anneal—Absolutely clean and uniform anneal . . . Previous degreasing usually unnecessary, however degreasing and cleaning can be part of the line . . . Design features eliminate scratching, marking, gouging, abrading and other surface defects.

Minimum Floor and Storage Space—Vertical design greatly reduces area of furnace . . . Continuous production eliminates investment in stored materials and storage space.

Economical, Efficient Operation—Automatic temperature and line control reduces operating labor costs. The compact design of the furnaces, including entry and exit seals, effects a decided fuel savings and minimizes the amount of atmosphere gas consumed. Together the two furnaces illustrated use only 250 to 300 CFH of atmosphere gas. The ideal annealing atmosphere used is supplied by the DREVER AMMONIA DISSOCIATOR.

The Drever Engineering Staff will be pleased to discuss with you the inherent advantages of these and other furnaces as they may apply to your specific requirements.

EXPERIENCE POINTS TO ➧ THE DREVER CO.

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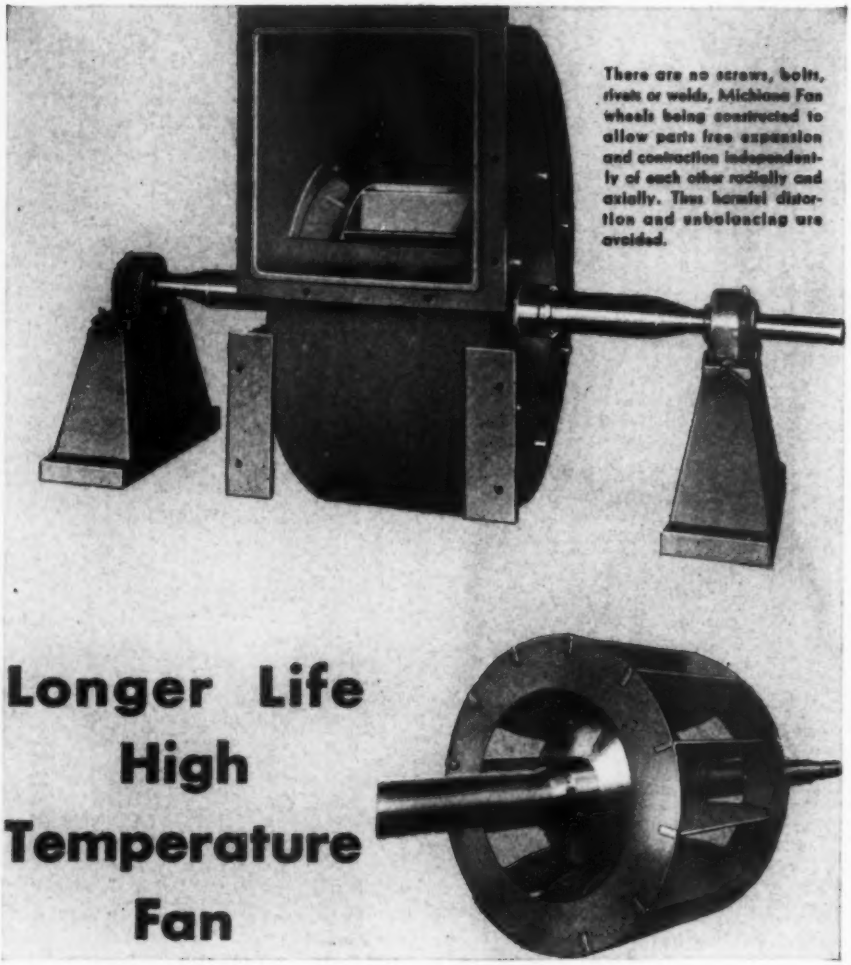

There are no screws, bolts, rivets or welds, Michiana Fan wheels being constructed to allow parts free expansion and contraction independently of each other radially and axially. Thus harmful distortion and unbalancing are avoided.

Longer Life High Temperature Fan

Designed especially for handling hot gases or products of combustion where temperature requirements range from as high as 1800° Fahr., Michiana Fans provide long-life continuous operating performance. The consistent uniformity of product, and improved output effected are well worth investigating now.

Michiana Fans of Michiana Heat-Resistant Alloys can again be produced, engineered to fit temperature and load requirements in capacities from 400 cu. ft. of air per minute.

For Special Applications

These fans, because of their design and construction, can be manufactured from any castable alloy and thus meet a wide variety of special requirements. For example, where abrasion is a factor, an abrasion-resistant alloy may be used; where resistance to corrosion is required—cast stainless steel may be employed. Thus MICHIANA FANS can be made of materials that cannot be produced in rolled form.

Our engineers are ready to make practical suggestions.

MICHIANA PRODUCTS CORPORATION, Michigan City, Ind.

MICHIANA
HIGH TEMPERATURE
FANS

Write for New Bulletin 645

Personals

FRANCES H. CLARK has resigned as metallurgist of the Western Union Co. to join the staff of the A.R.D. Corp., New York.

E. J. WALKER, recently discharged from the Army after serving at Oak Ridge, Tenn., on the Manhattan Project, is now employed by the Aluminum Co. of America at the Garwood, N. J., die casting plant.

GEORGE ESPEY, formerly senior research assistant in the department of metallurgical engineering, Case School of Applied Science, Cleveland, is now with the Lee Wilson Engineering Co., Cleveland, as metallurgical engineer.

The Alloy Casting Co., Champaign, Ill., announces the appointment of A. C. WOOLLEY, of the Woolley Instrument Service Co., Portland, Ore., as northwestern representative for stainless steel and heat resistant castings.

C. T. O'CONNELL has established his own cemented carbide tool engineering firm in Asheville, N. C. He will specialize in all phases of tool carbide problems as well as representing Kennametal, Inc., Latrobe, Pa.

EDWARD F. and EDWIN A. STACK, twin brothers and graduate chemical engineers, have become connected with the same industry. Edward is technical sales representative for MacDermid, Inc., in the Chicago territory, while Edwin, after being released from the Army, has joined the Udylite Corp., also in the Chicago area.

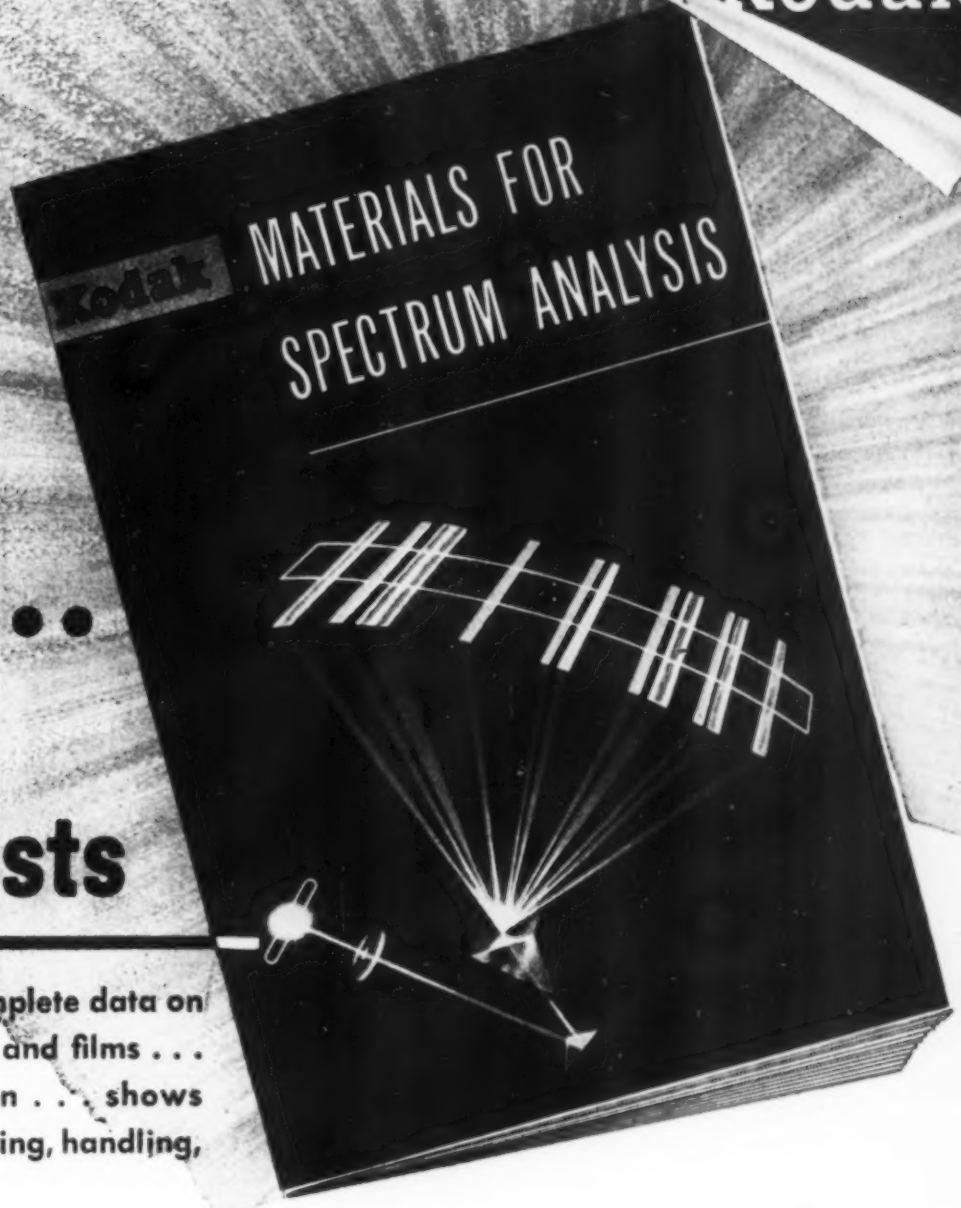
A. VERNE JACKSON, formerly project engineer for Chevrolet Motor Co., has joined the Muskegon Piston Ring Co. as sales representative in the Detroit office.

CAPT. R. K. WELLS, U. S. N., has recently been transferred from Terminal Island, Calif., and is now industrial manager, 8th Naval District, with offices at New Orleans.

ROBERT B. SMOCK has been promoted to physicist P-2 in Aviation Ordnance Dept. of Naval Proving Ground, Dahlgren, Va.

A. PHILIP BUNK, formerly associate welding engineer at New York Navy Yard, is now research engineer in the electrode division of the Metal and Thermit Corp. in the research and development laboratory in Woodbridge, N. J.

Kodak



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1. Elevating Screw now made of Stainless Steel
2. Ball Chuck now made of Stainless Steel
3. Plunger Rod Base now made of Stainless Steel
4. Stem of Plunger Rod now Hardened and Ground
5. Testing Head and Dial now Totally Enclosed
6. Penetrator Clamp Screw now an Automatic Clamp
7. All Operation Controls now Bunched Together
8. Dial of Gauge now has Zerominder Scale for Speed
9. Finish now Greatly Improved over War Times

Most used testers of our make lack all of these 9 improvements. All except those made recently lack many of them.

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Personals

FRED C. ZIESENHEIM has been named sales manager of the plastics and die casting machinery division of the Hydraulic Press Mfg. Co., Mt. Gilead, Ohio.

The retirement of JOHN JOHNSTON, director of the Research Laboratory of United States Steel Corp., has been announced. He has been succeeded by J. B. AUSTIN, formerly assistant director since 1928. Dr. Johnston, who has been engaged in many phases of research since his connection with the Massachusetts Institute of Technology in 1907, plans to spend his retirement in Maine.

THEODORE E. HACK has discarded his military title and is now associated with National Smelting Co., Cuyahoga Hts., Ohio, as production metallurgist.

S. J. BRODERICK has announced his new connection with the Department of Commerce as a technical consultant for duty in Germany.

THOMAS F. MIKA, formerly research chemist and metallurgist for the Victor Mfg. & Gasket Co., Chicago, is now with the market development division of the Shell Co. in Emeryville, Calif.

ARTHUR W. FRANK, formerly district manager, Hevi Duty Electric Co., Chicago office, has been appointed director of research with headquarters in Milwaukee. LAWRENCE S. TILDEN, formerly assistant district manager, will succeed Mr. Frank as district manager in Chicago.

The Wheelco Instruments Co., Chicago, has appointed JOHN E. ANDERSON to direct a new district sales and service office in Indianapolis.

GEORGE W. KURACHEK, formerly foundry metallurgist with the Wright Aeronautical Corp., is now connected with the Castalloy Co., Inc., Cambridge, Mass., as assistant foundry superintendent.

Carpenter Steel Co. announces the appointment of CARL O. ERICKE as district manager of the Detroit territory. He has been with the company as sales engineer since 1934.

A. J. NORDENSON is now associated with J. T. Thorpe, Inc., Los Angeles, handling engineering and sales.

NEW LOW BRAZING TEMPERATURES and NEW LOW SILVER CONTENTS . . .

are the big features of these new alloys that will put many metal joining jobs on a new low-cost basis. They save time, save heat, save man-hours and reduce alloy expense. Start these savings in your production now . . . LOW TEMPERATURE BRAZING NEWS NO. 36 gives you the facts. Write for a copy—today.

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Positive Protection For Painted Metal Surfaces

ACP phosphate coatings produce an excellent paint-bonding surface on metal parts and provide a foundation for a lustrous and lasting finish. There are various types depending on the kind of metal, its condition and the purpose for which it is to be used as well as the equipment facilities of the manufacturer. Some of these phosphate coatings are briefly described.

Cold SPRAY-GRANODINE in a short spray time forms a uniform, smooth, zinc phosphate coating—a superior base for lustrous, enduring paint finish. Cold Spray-Granodine is of special interest to fabricators of automobile bodies, fenders, refrigerators, cabinets and in general for proper preparation of sheet steel products for *durable, lustrous finishes.*

DURIDINE *simultaneously cleans and deposits a thin, tight, close-grained phosphate coating* on ferrous surfaces which provide the proper surface preparation for durable paint finish. The Duridine process is simple, economical and effective. Present spray washer installations of mild steel are adequate.

THERMOIL-GRANODINE used in an immersion process creates on steel an oil-absorbing, paint-bonding, crystalline coating of iron and manganese phosphate, integrated with the base metal. Treated surfaces, when oiled or painted, provide excellent protection against rust. Thermoil-Granodine furnishes excellent rust protection for tools, nuts, bolts and unpainted replacement machine parts.

Years of actual experience in the metal cleaning field have enabled ACP to develop chemicals and processes which are giving maximum results in cleaning and surface preparation for paint for varied types of metal and under varying conditions. ACP Technicians have had many years' experience in this field and will gladly consult with you and recommend the ACP products and processes which will most effectively and economically meet your requirements.

AMERICAN CHEMICAL PAINT CO.
AMBLER ACP PENNA.

Personals

The Acid Open Hearth Research Association has elected as officers for the following year: J. L. NICHOLS, American Locomotive Co., president; FRANCIS B. FOLEY, The Midvale Co., vice-president; F. C. T. DANIELS, Mackintosh-Hemphill Co., secretary; A. R. ALTMAN, Heppenstall Co., treasurer; and G. R. FITTERER, University of Pittsburgh, director of research.

The Micro-Ferrocart Products Division of Maguire Industries, Inc., Stamford, Conn., announces the appointments of THEODORE K. DAVIS as works manager; JOHN POLONETZ as chief engineer; E. RAYMOND ENGSTRAND as chief metallurgist; and KENNETH M. GLEZZER, as general sales manager.

CLARENCE JOHNSON has established an office in Beloit, Wis., as a consultant on research, inventions and engineering developments. For the past 18 years he was research engineer at Bailey Meter Co., Cleveland.

DAVID G. PETIGREW has been transferred from the Ball branch to the Philadelphia branch of the Whitehead Metal Products Co. as sales manager.

DONALD A. POTTER, discharged from the Navy in February, has been appointed research and development engineer for Universal Castings Corp., Chicago. During the war he did research in the Division of Physical Metallurgy at the Naval Research Laboratory, Washington, D. C.

JOSEPH N. PETERS has been named manager of the carbide and cast alloy division of the Jessop Steel Co., Washington, Pa.

W. H. BRANDT, formerly manager of the materials engineering department, has been appointed manager of the new Westinghouse special products engineering department.

The appointment of HENRY A. MULLEN as manager of resistance welding sales has been announced by Ampco Metal, Inc. He was previously connected with the Ford Motor Co. at Willow Run as welding engineer.

ROBERT W. MASON, Jr., formerly associated with the Lithium Co., Newark, N. J., has joined the development and research division of International Nickel Co., Inc.

18 Years Precision Casting Experience

MICROCAST PRECISION CASTINGS PROCESS

The TRADE MARK *for Genuine* High Precision CASTINGS

WHY MICROCAST IS THE LEADER

Fighteen years ago Austenal Laboratories originated the MICROCAST PROCESS for precision casting of intricate dental appliances to close tolerances using Vitallium*. In 1936, production on surgical appliances and jewelry specialties was pioneered by Austenal—another contribution by MICROCAST.

Another significant development was the application of the MICROCAST PROCESS to the production of turbo-supercharger blades which were produced by the millions during the war period.

This pioneering record of achievement is the reason why manufacturers are looking to Austenal and the MICROCAST PROCESS for the practical solution to intricate casting problems where close tolerances and high production are important. Perhaps this experience can help you, too.

INDUSTRIES NOW USING MICROCAST

Austenal is now producing quantity castings from a fraction of an ounce up to a pound for the following industries: Aircraft, Automotive, Bottle Cap, Business Machine, Dairy, Electrical, Hearing Aid, Heating, Phonograph, Photographic, Printing, Radio and Sewing Machine.

More complete information on MICROCAST is contained in a new booklet published by the Austenal Laboratories, Inc., originators of the MICROCAST PROCESS. This valuable new booklet is fully illustrated and describes many industrial applications for MICROCASTINGS as well as giving a step by step description of the process itself. Write for your copy today.

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Years ago industry employed Liquefied Petroleum Gas primarily as stand-by insurance against city gas failure or interruption of supply often caused during peak load months. But today, industrial plants are converting to economical, dependable Liquefied Petroleum Gas. No longer is their production hindered by interruption or short fuel supply. The dependable and economical source of LP-Gas supply today is Warren. Contact your nearest Warren Office today.

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"Falls Brand" Alloys

"FALLS" SPECIAL PATTERN ALUMINUM

Better castings result when "FALLS" SPECIAL PATTERN ALUMINUM is used:

. . . more fluid than other aluminum alloys, it will run thin sections more readily.

. . . "top shrinkage" is eliminated — no soldering to build up depressed areas.

. . . since heavy gates and risers are not needed, much extra casting expense is eliminated.

. . . with only a trifle less linear shrinkage than other aluminum alloys, no change in the pattern scale for running No. 12 Alloy is needed.

. . . checking is rarely encountered.

WRITE FOR COMPLETE DETAILS

NIAGARA FALLS SMELTING & REFINING DIVISION
Continental-United Industries Co., Inc.
America's Largest Producers of Alloys
BUFFALO 17, NEW YORK

Electrolytic Manganese*

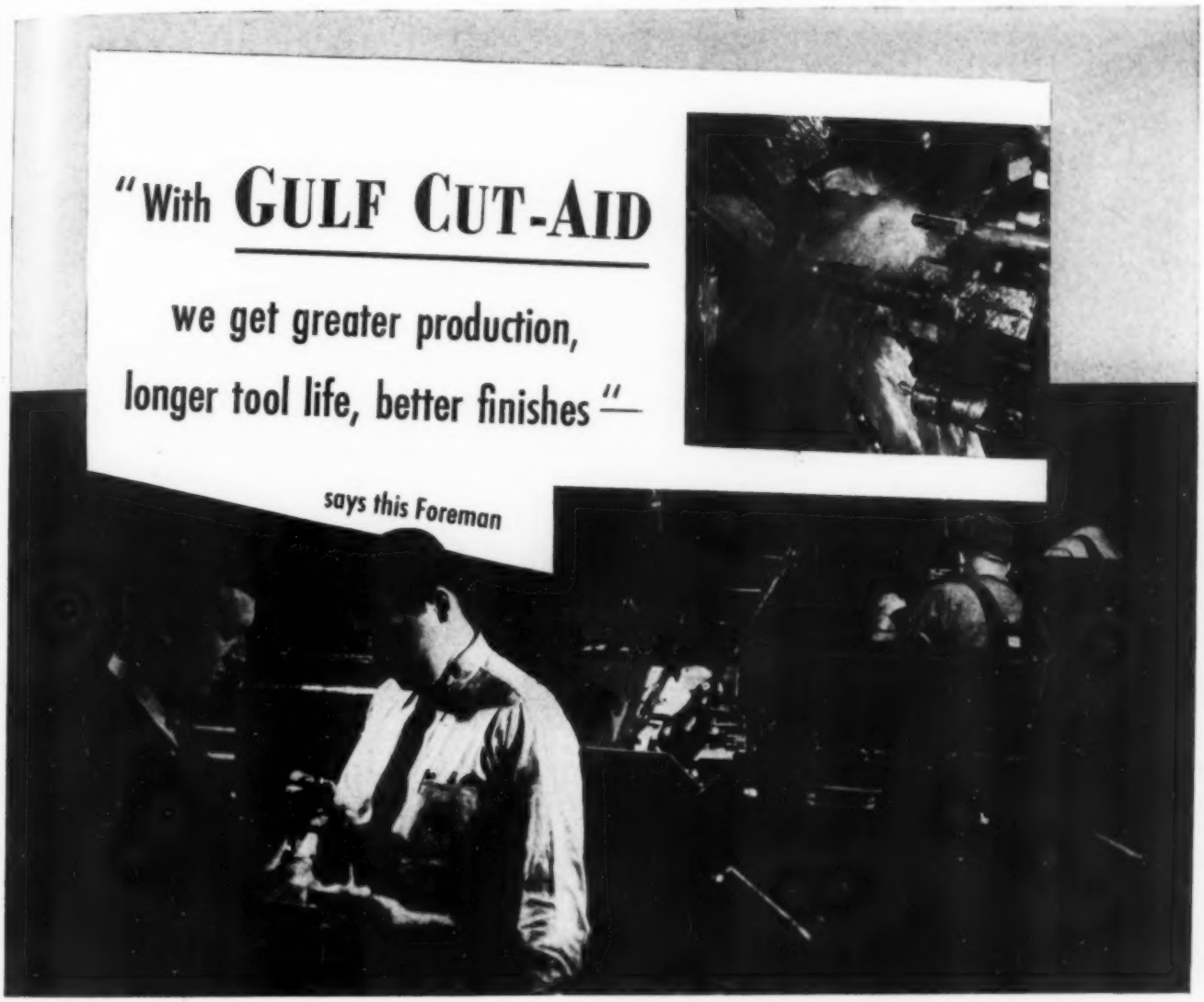
THESE TESTS in cooperation with industry are part of the Bureau of Mines program of investigations of methods of utilizing low-grade domestic manganese ores. The primary purpose of the cooperative tests at Atlas Steel Casting Co. was to investigate the usability of electrolytic manganese in the manufacture of low-carbon and medium-carbon steels with moderate manganese contents and to determine whether any modifications in melting practice would be necessary.

The inability to remove phosphorus in the acid practice makes the use of phosphorus-free electrolytic manganese desirable. On the basis of eight acid openhearth and seven acid electric heats made with electrolytic manganese, it was concluded that electrolytic manganese is entirely acceptable. The manganese recoveries from additions in the ladle for openhearth heats and either in the ladle or on top of the slag for electric heats were at least as good for the electrolytic manganese as for the normal ferromanganese. No adverse effects were observed in the heats to which large ladle additions of electrolytic manganese were made. There was no evidence of undue chilling or manganese segregation. Electrolytic manganese can be added to the ladle in larger quantities than ferromanganese.

Heats blocked at the usual carbon content require additions of pig iron to recarburize that would not be needed if ferromanganese were used; regular use of electrolytic manganese probably would result in the melter blocking the heat at higher carbon. Reboiling caused by the late pig iron addition may contribute to better quality in some instances. The steel made with electrolytic manganese was no cleaner than the usual steel, but the mechanical properties were better.

Two acid electric heats of carbon steel and one of low-alloy steel at Detroit Steel Casting Co. in which ladle additions of electrolytic manganese were made showed no marked difference *(To p. 1256)*

*Abstracted from "Electrolytic Manganese in Acid Steel Tests at Atlas Steel Casting Co. and the Detroit Steel Casting Co.", by R. T. C. Rasmussen. Bureau of Mines, R. I. 3830, November 1945.



The Department Foreman (right) consults with a Gulf Lubrication Engineer on the performance of Gulf Cut-Aid in machining a brass part. *(Photos courtesy of the Corbin Screw Division of American Hardware Corporation.)*

"PRODUCTION of intricate brass parts on our six-spindle automatics jumped 17 per cent after we switched to Gulf Cut-Aid," says this Department Foreman. "In addition, Cut-Aid keeps the tools and work much cooler, helps us get better finishes, longer tool life, and maintain closer tolerances."

This experience is typical of hundreds reported by shops that use Gulf Cut-Aid for machining nonferrous metals. For this revolutionary cutting oil consistently shows better results on this type of work!

It will pay every machine shop to investigate the full possibilities of Gulf Cut-Aid and other Gulf production-proven cutting oils. Call in a Gulf Lubrication Engineer today and let him show you how they can help you improve your machining practice. Write, wire, or phone your nearest Gulf office.

Gulf Quality Cutting Oils

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The New AJAX
125 kw. Furnace
for the
Aluminum Alloy Foundry

● Especially designed for the melting of finely divided aluminum alloy particles like turnings, chips and unbaled foil, this furnace is operated on the twin coil induction principle. Oxidation losses are reduced considerably and yields of 95% to 96% of the dry weight of the charge are obtained with this unit, in view of the rapid melting and the low temperature prevailing in the hearth during the melting operation. These units promise large savings in the recovery of aluminum alloy scrap of all kinds, in addition to all the other advantages of induction melting.

AJAX ENGINEERING CORPORATION

Trenton 7, New Jersey

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Associate Companies: AJAX METAL COMPANY, Non-Ferrous Ingot Metals and Alloys for Foundry Use
AJAX ELECTROTHERMIC CORP., Ajax-Northrup High Frequency Induction Furnaces
AJAX ELECTRIC CO., INC., The Ajax-Hultgren Electric Salt Bath Furnace
AJAX ELECTRIC FURNACE CORP., Ajax-Wyatt Induction Furnaces for Melting

Aircraft Engines*

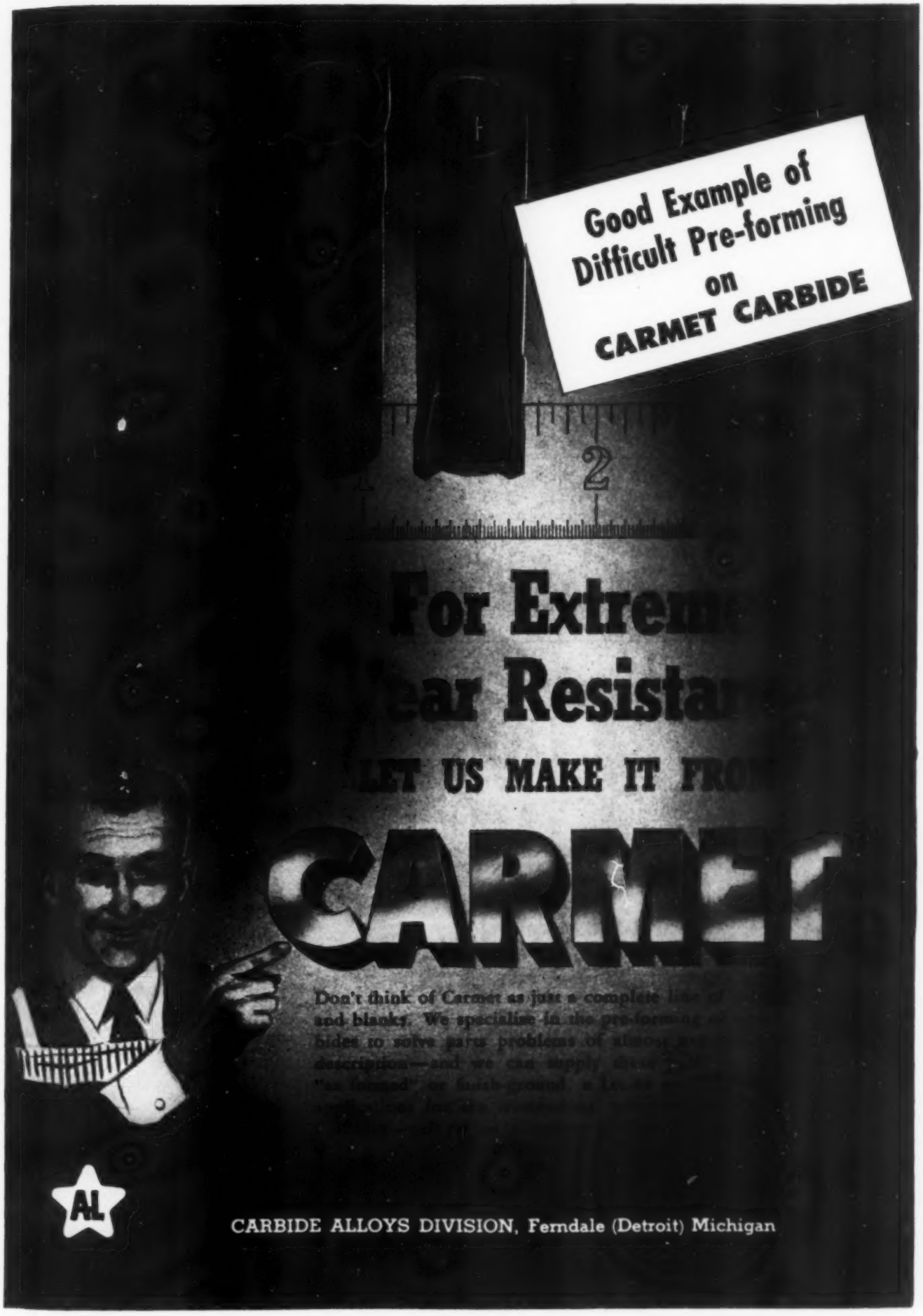
AS FAR AS materials used in aircraft engines are concerned, the issue rests between steel and aluminum. The copper alloys are used only in certain special applications, and magnesium, despite heroic efforts, has not gained real ground for some years.

Pistons — Wrought aluminum pistons are universal in high power units. Y alloy and RR59 are used in England, but some American and German pistons have been made in the heat treatable high silicon alloys. Excellent cast pistons can be made but the modern pressed piston offers the reliability and uniformity of forgings combined with closer tolerances than castings. Strength at temperature is necessary in the crown but cold strength is required in other parts. Pistons almost never fail in the crown but rather by pulling the bosses away from the crown. The best treatment is to quench the piston in boiling water to minimize internal stress or design the piston so that stresses in service are equalized as much as possible. The piston should also be stressed on the elastic limits up to 480° F., the temperature about halfway down the skirt.

Cylinder Heads — The hottest spot of cylinder heads is the narrow neck between exhaust and inlet. Actual failures do not occur here but the alloy creeps readily so gas leak can take place behind the valve seat. The cylinder head is so complex that a fully heat treated head is full of internal stress. The head can be air cooled from the solution treatment or even fully annealed, since the effect of heat gradients is far less serious than with the piston. The problem of joining an aluminum head to the steel barrel has not yet been satisfactorily solved. Forged heads are definitely superior to cast heads. Y alloy resists the cumulative softening and diffusion slightly better than does RR59.

Crankcases — In air cooled engines, crankcases are made from drop forged or pressed Y, RR56 or duralumin-type alloys. Forged high-strength aluminum crankcases indicate the danger of internal stress. Fully quenched and aged RR56 caused an *(Cont. on p. 1260)*

*Abstracted from "Aircraft Engines. Application and Possible Development of Nonferrous Metals", by E. Wood. *Metal Industry*, Dec. 28, 1945, p. 435 to 439.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CARBIDE ALLOYS DIVISION, Ferndale (Detroit) Michigan

Effect of Residual Stress on Fatigue*

A QUENCH from the solution treatment temperature was utilized to produce residual stresses in aluminum alloys, which were then submitted to fatigue tests. The experiments were made on two forged alloys of the duralumin type (D.T.D.150 and B.S.S.L45) and one cast alloy containing 4% copper (D.T.D.298). Results of rotating cantilever fatigue tests at 50,000,000 cycles are given in the table.

Range of Stress in Fatigue Tests

Condition	D.T.D.150	B.S.S.L45	D.T.D.298
	Plain Specimens		
A—stress free	± 23,070 psi.	± 21,950 psi.	± 11,200 psi.
B—residual stress	± 21,950	± 21,950	± 13,440
	Notched Specimens		
A—stress free	± 9,855	± 9,630	
B—residual stress	± 17,470	± 13,890	
C—residual stress	± 15,905	± 13,890	

Specimens in condition A had been quenched in bulk in hot water and it was assumed that the residual stresses were negligible since the machining of the test pieces involved the removal of considerable material. Specimens in condition B were machined, then reheat treated by quenching into water at room temperature. Specimens in condition C were machined to diameter, reheat treated by quenching into water at room temperature, and then notched.

No measurements of residual stress were made, but from the literature it may be assumed to be several thousand pounds per square inch. The stresses had little effect on the fatigue strength of plain specimens of wrought material, but on the specimens with annular notches, increases were obtained of up to 80% above the strength of the material not containing residual stresses. Plain specimens of the sand-cast material showed a 20% increase due to residual stresses.

Rotating cantilever tests on notched tubular specimens of B.S.S.5T4 (a duralumin-type) were made in five conditions with the following stress ranges:

Condition A — Heat treated only: ±9630 psi.

Condition B — Heat treated and subjected to a heavy sinking pass: ±5375 psi.

Condition C — Same as B, then stretched about ½% and reeled: ±6270 psi.

Condition D — Same as A, then stretched 2%: ±8510 psi.

Condition E — Same as B, then stretched 2%: ±6720 psi.

Splitting tests showed a fairly small longitudinal compression on the outside and a corresponding tension inside in condition A. Condition B gave high tensile stresses on the outside and compression on the inside. Condition C showed that the stresses *(Cont. on p. 1256)*

*Abstracted from "Some Experiments on the Effects of Residual Stresses on the Fatigue of Aluminum Alloys", by G. Forrest. *Journal* of the Institute of Metals, V. 72, 1946, p. 1-17.

Eclipse
PRESSED STEEL POTS
12 "Points" to the Good
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1 Low first cost, low pot hour cost.
2 Absolute freedom from defects.
3 No grain growth at red heat.
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9 Quicker, more uniform heating of bath.
10 Substantially increased production in a given day.
11 High strength at elevated temperatures.
12 Thin, uniform and straight side walls offer increased capacity.

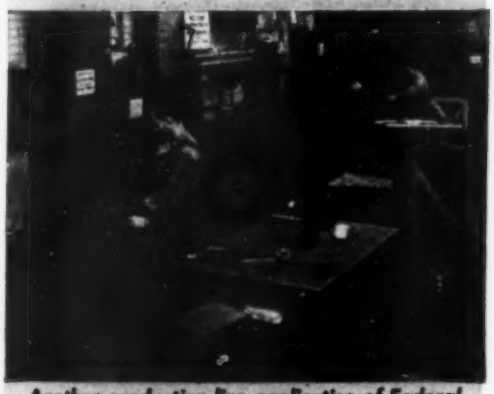
Eclipse Pressed Steel Pots offer the most dependable service PLUS reduced working costs, for practically all heat treating operations below 1650 deg. F. (and some higher), as well as for the melting of the lead base alloys.

Write for illustrated Bulletin N-1, showing various shapes, standard sizes and other details.

Representatives in all principal cities.

When Production Planning Sheet Metal Goods *REMEMBER..*

For production welding of freeze boxes or furnaces, stoves or store fixtures, all types, all sizes.



Another production line application of Federal Rocker Arm Spot Welders.

One of a line of Federals in a large scale job shop making "anything" from sheet metal.

Federal Welders Raise Standards of Metal Fabrication... In Small Shop or Large Plant

The business of making things from metal has come a long way since the days when everything from rainspouts to refrigerator liners was roll-seamed and soldered, not too many at a time, by craftsmen known (with all due respect) as "Tin Knockers". Today Federal Spot Welders play a big role in making Metal Fabricators out of such craftsmen.

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Residual Stresses

(Cont. from p. 1254) due to sinking were considerably modified by stretching and reeling. Stretching 2% reduced the residual stresses to small dimensions regardless of the prior condition (conditions D and E).

The effect of residual compressive stresses at the root of an annular notch was determined by preloading an extruded rectangular section (B.S.S.6L1) in tension. A 100% increase in the rotating cantilever fatigue strength was obtained by prestressing to a nominal stress of 56,000 psi. (on the area at the root of the notch). Range of stress for 50,000,000 cycles was ±22,400 psi. for plain specimens, ±7840 to ±8960 for notched specimens, and ±17,920 for notched specimens which were preloaded in static tension.

Single spot welds on Alclad D.T.D.546A were preloaded in the direction of subsequent application of the fatigue loads. The fatigue strength showed an increase of 50% over that of the original welds under fluctuating shear stresses.

The main conclusion to be drawn is that, under the complex stress conditions at the root of an annular notch, compression stresses — whether applied by quenching or mechanical action — may result in an extremely large increase in fatigue strength.

Electrolytic Manganese

(Starts on page 1250) in properties, susceptibility to heat treatment, nonmetallic inclusions, or manganese yield from comparative heats in which the manganese addition was made in the ladle as ferromanganese. Comparison of the deoxidizing efficiency of the two forms of manganese was impossible because of the severe deoxidation by much more active deoxidizers used to insure soundness of green sand castings.

The mechanical properties were similar to those of heats in which ferromanganese was used, but the electrolytic manganese heats showed consistently higher ductility and quicker response to heat treatment. This higher and more quickly attained ductility is also reflected in the consistently higher quality factor for the electrolytic manganese heats and the shorter tempering time required for the maximum quality factor.

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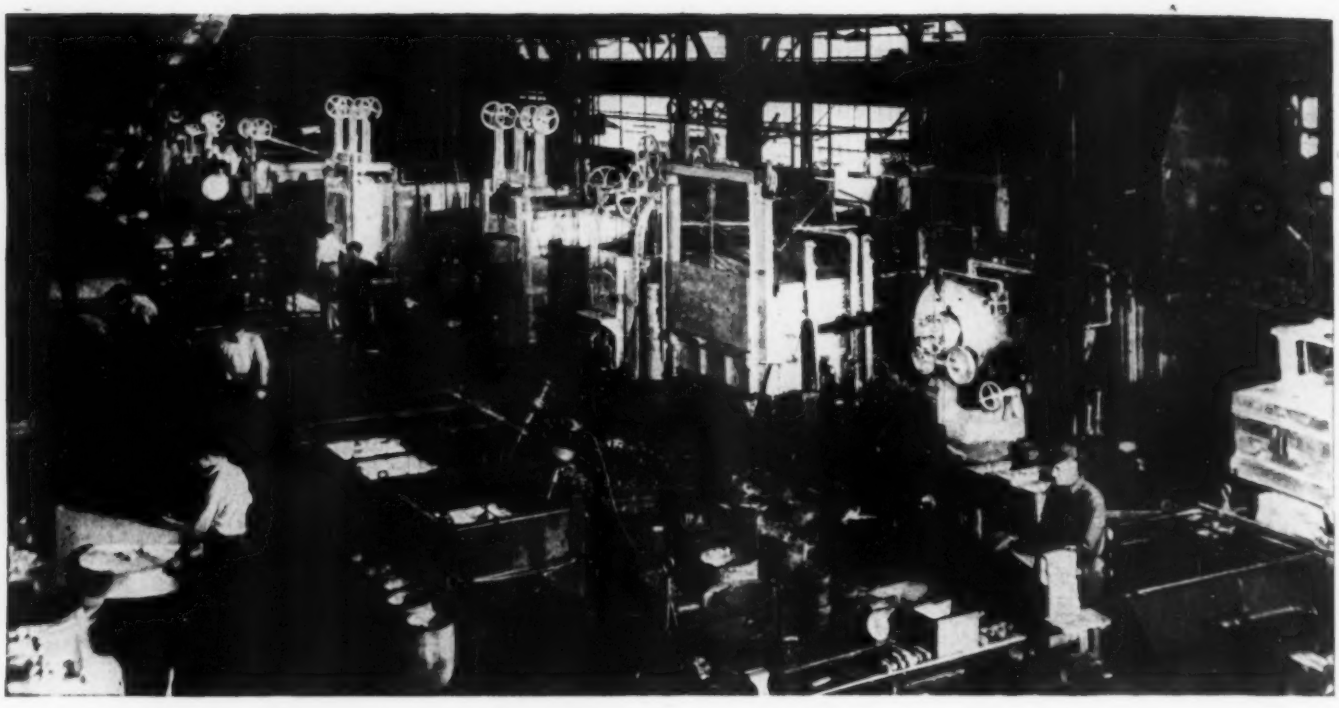

Long experience and concentrated effort in one field have made the commercial heat treater the outstanding expert in the heat treatment of ferrous and nonferrous metals.

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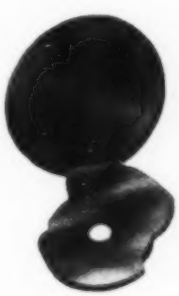
demanded: RIGIDITY plus WEAR-RESISTANCE

found: in CAM BLANKS cast of ABSCO-MEEHANITE

When service conditions demand rigidity and wear-resistance plus a high degree of machinability, castings of Absco-Meehanite have been selected after trials in which steel plates and ordinary iron castings were also tried. They proved themselves in performance.



In one instance a manufacturer of instrument parts made Swiss type screw machine cams from Absco-Meehanite cast blanks. In addition to the triple combination of qualities mentioned above, the cam blanks had to undergo flame hardening without distortion, these particular castings being hardened to 53 to 55 Rockwell C scale.

Longer cam wear in close tolerance work is one illustration of the benefits that follow Absco-Meehanite's close matching of metal characteristics to job needs. Discuss *your* requirements with Absco engineers. American Brake Shoe Company, 230 Park Avenue, New York 17, N. Y.

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TIGHT, STRONG JOINTS every time . . . because Cherry Rivets have special characteristics that establish superiority over all other blind fasteners: (1) greater shank expansion; (2) greater allowable variance in material thickness for a given rivet length.

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MONEL, STEEL, brass and aluminum comprise the Cherry Rivet material classification. There are three types, two head styles, a range of diameters and lengths.

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Aircraft Engines

(From p. 1252) epidemic of fatigue failures. The cure was air cooling and aging at 390° F. A better crankcase was obtained although the strength as indicated by test bars was decreased. Castings are used on liquid cooled in-line engines because of their shape. An American engine uses a forged steel crankcase; the high strength and modulus and adaptability for rigid attachments more than compensate for the high density.

Castings — Most minor parts are made of RR50 alloy with the lower stressed parts in D.T.D.424 or 428. RR50 is very reliable. Y alloy is the best choice where higher strength at temperature is required. L33 is unsurpassed for "die castability" but has low strength.

Bearings — The author believes high-tin alloys have no superior as bearing metals. The bearing of the future will probably be a sponge or a powder compact or a mechanical mixture, rather than a simple cast or plated alloy.

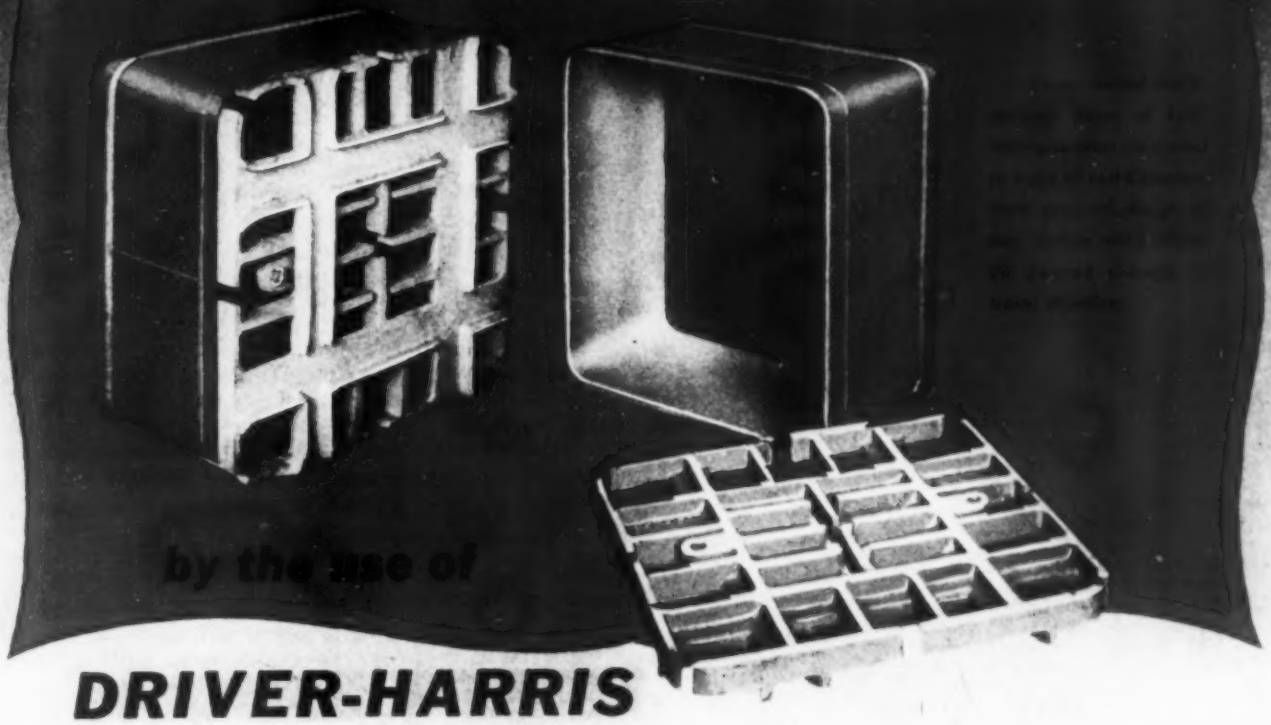
Magnesium — The outlook for magnesium alloys is not as promising as it once seemed. Cast alloys find some applications for low stressed details, but its low creep strength and above all its peculiar susceptibility to notches and changes in section have led to many setbacks.

Copper — The author favors the 85-5-5-5 copper alloy for small bushes and slip rings. Phosphor bronze (chill cast) is superior to cold drawn bronze for valve guides. Cold drawn or chill cast phosphor bronzes are well established for bushes and liners. Aluminum or aluminum - nickel - iron - manganese bronzes are used in limited though important applications.

Test Values — In general, far too much attention has been paid to high test bar properties and nowhere enough attention to the properties of shapes and structures. High proof: ultimate ratios in themselves are not necessarily good. For example, duralumin is the best light alloy for propellers, although its proof strength is the lowest of the high-strength alloys. The newer high-strength alloys such as X76S give appreciably higher fatigue strengths in rotary bending but are no better under direct tensile compression. Their notch sensitivity is higher and they are susceptible to small variations in composition. Alloys such as D.T.D.324 can *(Cont. on p. 1262)*

LIVE LOAD BOOSTED

Dead Weight Cut



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A prominent midwestern malleable foundry wanted to speed up production of small parts, heat treated in pusher-type furnaces. To do this, dead load had to be reduced and the cycle shortened—without affecting the quality of the output.

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Remember, only Driver-Harris makes Nichrome* Chromax*, and Cimet*—and only Driver-Harris has had 30 years' experience in engineering and casting high heat-resisting, nickel-chrome alloy equipment. Depend on this "team" to provide an expert solution to your heat-treating problem. Why not investigate its possibilities, today.

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D/H
SPECIAL PURPOSE ALLOYS SINCE 1919

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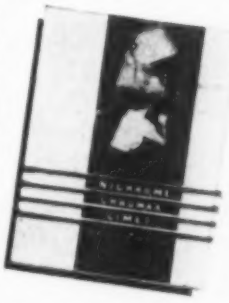
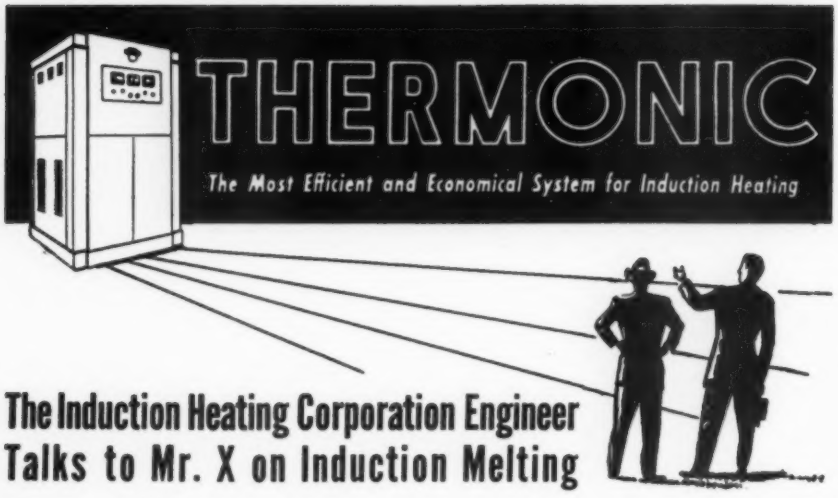
The 3 high heat-resisting nickel-chrome cast D-H alloys—NICHROME*—CHROMAX*—CIMET*—are fully described in this catalog F-40. Write for a copy.





The Induction Heating Corporation Engineer Talks to Mr. X on Induction Melting

MR. X . . . . Your THER-MONIC Induction Heating Equipment is certainly adaptable to a wide range of heating applications. But suppose the size and shape of the work to be heated vary considerably. How can the same induction heating unit heat treat or braze such a variety of parts?

ENGINEER . . . . This is done by using interchangeable work coils. The use of ready-made inserts of the patented THER-MONIC "Master Coil" Set on a basic master coil greatly facilitates changeovers from one operation to another. These inserts can be built-up to any desired shape or thickness to produce an almost unlimited range of heat patterns. Set-up time is thus reduced to the simple selection of inserts best suited to the heating problem. With the proper work coil installed, a single induction heating generator can heat either ferrous or non-ferrous materials rapidly and efficiently.

MR. X . . . . By the way, I've been wondering about the application of your high-frequency induction heating equipment to the field of melting. I know that large melting furnaces in many steel and brass mills are heated by relatively low frequencies.

ENGINEER . . . . I was coming to that. Melting is one of the oldest and largest applications of induction heating. As you may know, the induction melting furnace is fundamentally a transformer, whose primary is the work coil, and whose secondary is the mass of metal to be melted. Although lower frequencies are more economical for large melts, there are many installations, ranging in melting capacity from several ounces up to 50 pounds, which utilize higher frequencies. High-frequency melting was first used in the precious metals field, but has found even wider application in small runs of tool steels and other alloys requiring close temperature control and a high degree of purity. One of the more recent applications of high-frequency heating is in the production of precision centrifugal castings, where rapid, small-lot melting is necessary. High frequencies are also used to best advantage to sinter tungsten carbide and process other powdered metals.

MR. X . . . . What makes the higher frequencies so useful in small-lot melting?

ENGINEER . . . . That's because of the ability of the higher frequencies to transfer more energy. A single THER-MONIC high-frequency generator can provide energy for a series of crucibles, located far from the generator. Where ceramic crucibles are used, high-frequency currents are induced directly in the metal, stirring the metal as it melts. Metal loss is extremely low. A newly developed THER-MONIC load-control device permits instantaneous regulation of energy transfer into the melt. This load control increases or decreases the energy input into the work. Thus, after the metal is melted, energy input into the melt can be reduced to hold it at any required temperature. Likewise, during the melting cycle the load control maintains a maximum load by compensating for the variations occurring in loading characteristics of the melt. This is particularly effective in melting magnetic materials, which lose their magnetic properties upon passing through the Curie point.

MR. X . . . . What is the advantage of using a load control after the metal loses its magnetic properties?

ENGINEER . . . . When melting magnetic materials, it is somewhat difficult to transfer energy into the melt after the magnetic properties of the metal disappear. It is essential then to use a load control to compensate for this loss of energy transfer. The load control is installed in the output circuit of high-frequency equipment, enabling the current flow to be controlled and the power into the work held at maximum during the entire heat cycle. It permits accurate temperature regulation and greatly improves the process for small-lot melting. THER-MONIC load control really achieves a new high in induction-melting efficiency.

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Largest Producers of Electronic Heat Treating Equipment for Forging
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(Starts on p. 1252) give hot fatigue strength as good as RR56, but the creep strength at the same temperature is appreciably lower than that of the latter. Magnesium alloys on straightforward notched fatigue tests do not appear to be as bad in notch sensitivity as they do in service.

Future Trends — Users and suppliers should look at metals with more open minds. It is possible that quenching and aging are not the best treatment for aluminum alloys. The general superiority of steel may be a function of the release of macro and micro internal stress during tempering. A piece of metal should be viewed as a structure or shape doing a job and the designer should not be misled by some property of round bars. In spite of the work on notch sensitivity and triaxial stresses, much good material is rejected and unsuitable material processed because of a rigid and unimaginative interpretation of test bar data.

More up-to-date metallurgy and fundamental research are needed. For example, why do light alloys behave entirely differently in fatigue than steel? Mere test bar figures and information on special properties are not enough if internal stresses or notch sensitivity lead to dangerous failures.

Aluminum for Automobiles*

THE PROPERTIES and processing of aluminum and its alloys are discussed with particular reference to their use in automobiles. As far as physical properties are concerned, the designer must take into account the rather high coefficient of expansion, the comparatively low elastic properties and the low specific gravity. The higher ratio of proof to ultimate stress of the strong aluminum alloys requires a different factor of safety from that used for steel. The inherent resistance to corrosion of aluminum and its alloys is considerably higher than the resistance of ordinary steel to rusting.

Although aluminum and its alloys may readily *(To page 1266)*

*Abstracted from "Aluminum and the Automobile Engineer", by E. G. West. The Institution of Automobile Engineers *Journal*, V. 14, Jan. 1946, p. 109 to 146.

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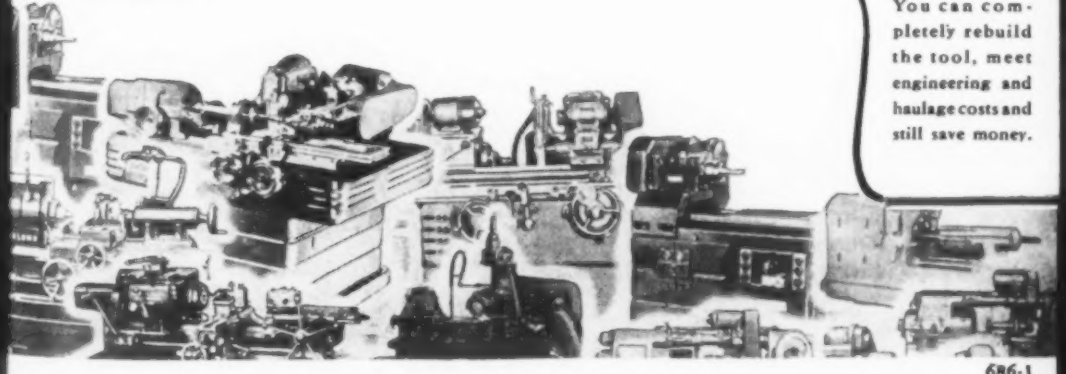

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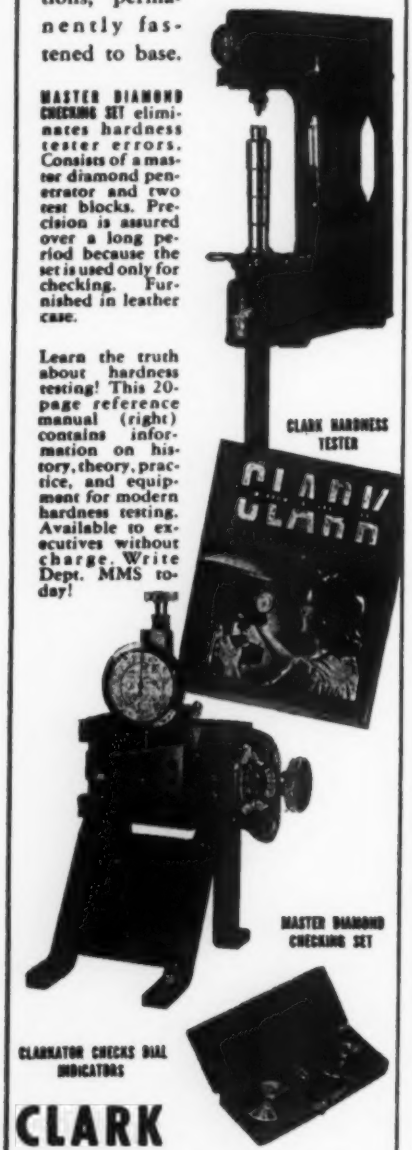


CLARK
INSTRUMENT, INC.
10200 Ford Road • Dearborn, Mich.

Aluminum for Autos

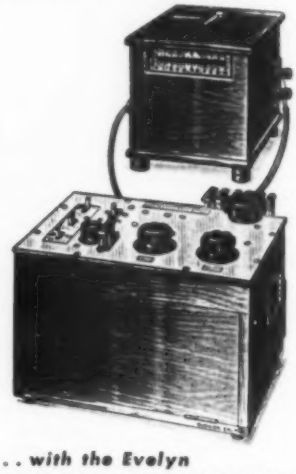
(Cont. from p. 1262) be fabricated and formed by all the usual metallurgical processes, some of the working characteristics may determine the design of a component to a greater extent than the strength or other requirements made necessary by the known service conditions. The advantages of low weight, high conductivity, good resistance to corrosion and the wide range of forming methods available go far toward outweighing the principal disadvantage of relatively high initial cost.

There has been a steady development in the use of aluminum for power units. The Merlin XX aircraft engine uses 45% by weight of aluminum. Although automobile engines do not use this high proportion of aluminum, this example shows the possibilities. Most aluminum alloy engine components are in the form of castings, although forged pistons and connecting rods are used. Motor cycle engines may show more immediate advantages resulting from the use of light alloys than engines for heavier vehicles. Components which have been successfully cast in aluminum alloys include cylinder head and barrel, pistons, carburetor, gear box, clutch plate, magneto housing and filler cap. Engine components must be designed in terms of the properties of aluminum rather than attempting simple substitution for ferrous materials.

The lack of interest in the use of aluminum for motor cars and motor cycles is chiefly economic (the higher cost of aluminum sheet as compared with steel) and partly technical — in particular the difficulty in joining body panels together. The most satisfactory initial step is to use aluminum alloys for the doors, luggage lid, bonnet top and sides, windscreen and windows. Experience abroad has shown that aluminum alloys are successfully employed for engine components, gasoline and oil tanks, wheel rims, saddle frame, unsprung front fork members, steering damper body, mudguards, covers, wheel nuts, and accessories.

In commercial vehicles, designers and operators both desire to reduce vehicle weights in relation to pay load. A great deal of aluminum alloy has been used in vehicle construction on the Continent, particularly in France. Three trucks were built to carry long lengths of aluminum alloy *(Cont. on p. 1270)*

Speedy • Accurate
CHEMICAL ANALYSIS



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PHOTOELECTRIC COLORIMETER

For more than ten years this instrument has rendered outstanding performance in nearly every field of chemical activity. Distinguished by almost classic simplicity of design, this colorimeter is noted for its sturdy and enduring construction and for its unusual reliability and freedom from the mechanical and electrical deficiencies which can prove so costly in the efficient chemical laboratory.

Because of the unique accuracy, speed and simplicity of operation which it affords, the Evelyn Colorimeter is widely used in both research and routine control laboratories in the metallurgical field. A detailed discussion of the design of this invaluable analytical tool is presented in our twelve-page Bulletin 460, available on request.

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- Compact; self-contained
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Described in Bulletin 270-A

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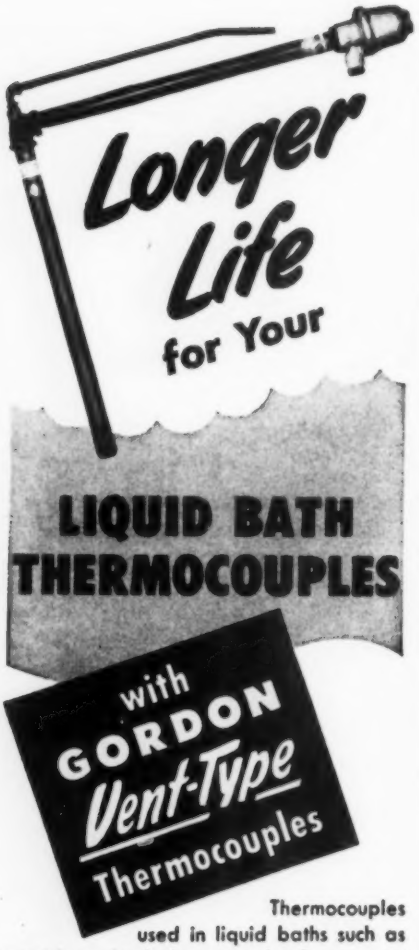

Thermocouples used in liquid baths such as cyanide and salts have previously worn out rather rapidly owing to the fact that gases apparently pass right through the protecting tube, collect inside, contaminate the thermocouple and shorten its life.

The new Gordon vent-type thermocouple eliminates this collection of gases by providing a vent through which they are allowed to escape. It is also possible to blow a small amount of air from a convenient air connection through the tube to remove these gases.

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(From p. 1266) sections and tubes. These trucks were designed to take advantage of the low modulus of elasticity by allowing a certain amount of deflection of the whole vehicle to take place, such as, for example, would be imposed by uneven roads, without imposing undue stress on the material. All have run more than 120,000 miles with complete satisfaction.

Light alloys have been used extensively in passenger transport vehicles. The applications include roofing, side panels, canopies, bodies, stair stringers, stanchions, grab rails and window frames.

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Corrosion Tests on Magnesium*

PREVIOUS corrosion tests on as-cast alloys had shown a corrosion rate in 3% sodium chloride solution between 0.5 and 1.0 mg. per sq.cm. per day when the metal was low in iron or contained sufficient manganese together with a "normal" iron content of about 0.02%. Similar tests at the Royal Aircraft Establishment and in America resulted in a corrosion rate of about 0.10 to 0.20 mg. per sq.cm. per day. There were three differences between the immersion test as used at the R.A.E. and the authors' test:

1. The R.A.E. used freshly made solution; the authors used the solution continually.

2. The R.A.E. prepared the surface with emery papers, finishing with moist pumice powder; the authors abraded the surface with 1F emery paper. *(Cont. on p. 1273)*

*Abstracted from "The Influence of Some Different Surface Preparations on the Corrosion of Magnesium-Base Alloys of Low and Normal Iron Content", by F. A. Fox and C. J. Bushrod. *Journal* of the Institute of Metals, V. 72, 1946, p. 51 to 63.

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Corrosion of Magnesium

(Continued from page 1260)

3. Degreasing was by benzene vapor at the R.A.E. and carbon tetrachloride at the authors' plant.

Preliminary tests indicated that the important factor was the method of surface preparation. Therefore samples with varying iron content (0.002%; 0.005%; 0.011 to 0.016%) were prepared for test by three methods: *(a)* abrasion on glass paper; *(b)* abrasion with 1F emery paper followed by 0 emery paper and moist pumice powder; and *(c)* preliminary emery preparation followed by hand polishing using a Selvyt cloth moistened with a suspension of alumina. The corrosion rates of these specimens in 3% sodium chloride solution were compared with those previously found for specimens prepared on 1F emery paper. The specimens prepared on 1F emery paper corrode much more rapidly than those with the other methods of surface finish, all of which corrode at about the same rate. Furthermore, while specimens of varying iron content all corrode at substantially the same rate when prepared on 1F emery paper, metal of low iron content corrodes at a slower rate than that with higher iron when the other preparations are used.

Surface roughness was not a factor, since the 1F emery paper gave a value less than that of the glass paper. The adverse effect of emery preparation may be due to iron oxide pickup by the metal surface, since the emery removed from the 1F paper contained about 7% iron as Fe_2O_3. Previous work on the protective value of various oxide films deposited on Elektron AM503 sheet showed that films containing appreciable quantities of oxides (or hydroxides) of iron caused accelerated corrosion. An important objection to this theory lies in the good corrosion performance of the emery-prepared specimens of low iron and manganese content reported previously as compared with specimens of higher iron and low manganese content prepared in the same way.

Additional work on this subject is needed, particularly on specimens subsequently chromate treated and painted. This dependence of the enhanced corrosion resistance of high-purity metal on the surface preparation may prove to be an important practical consideration in the commercial assessment of these materials.

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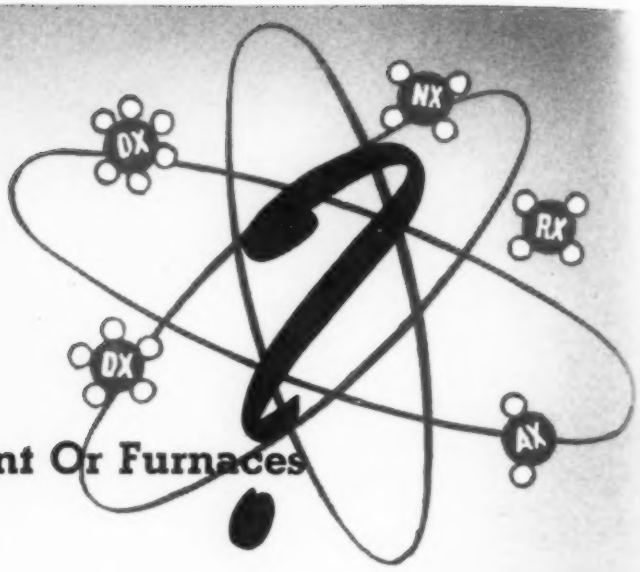

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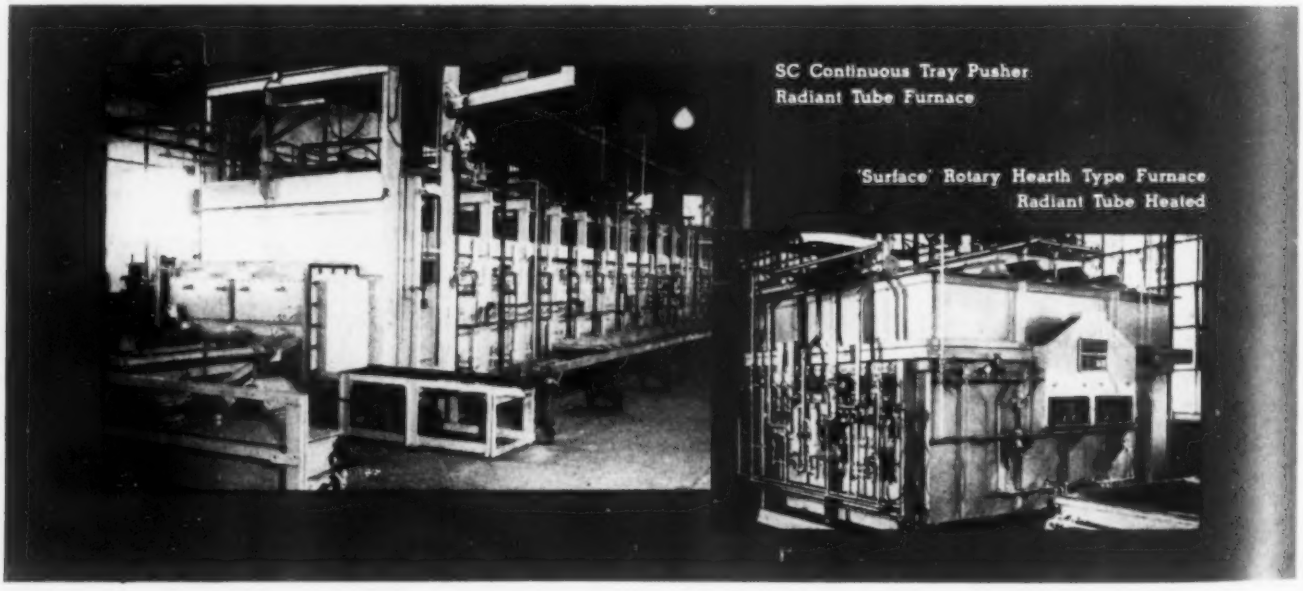

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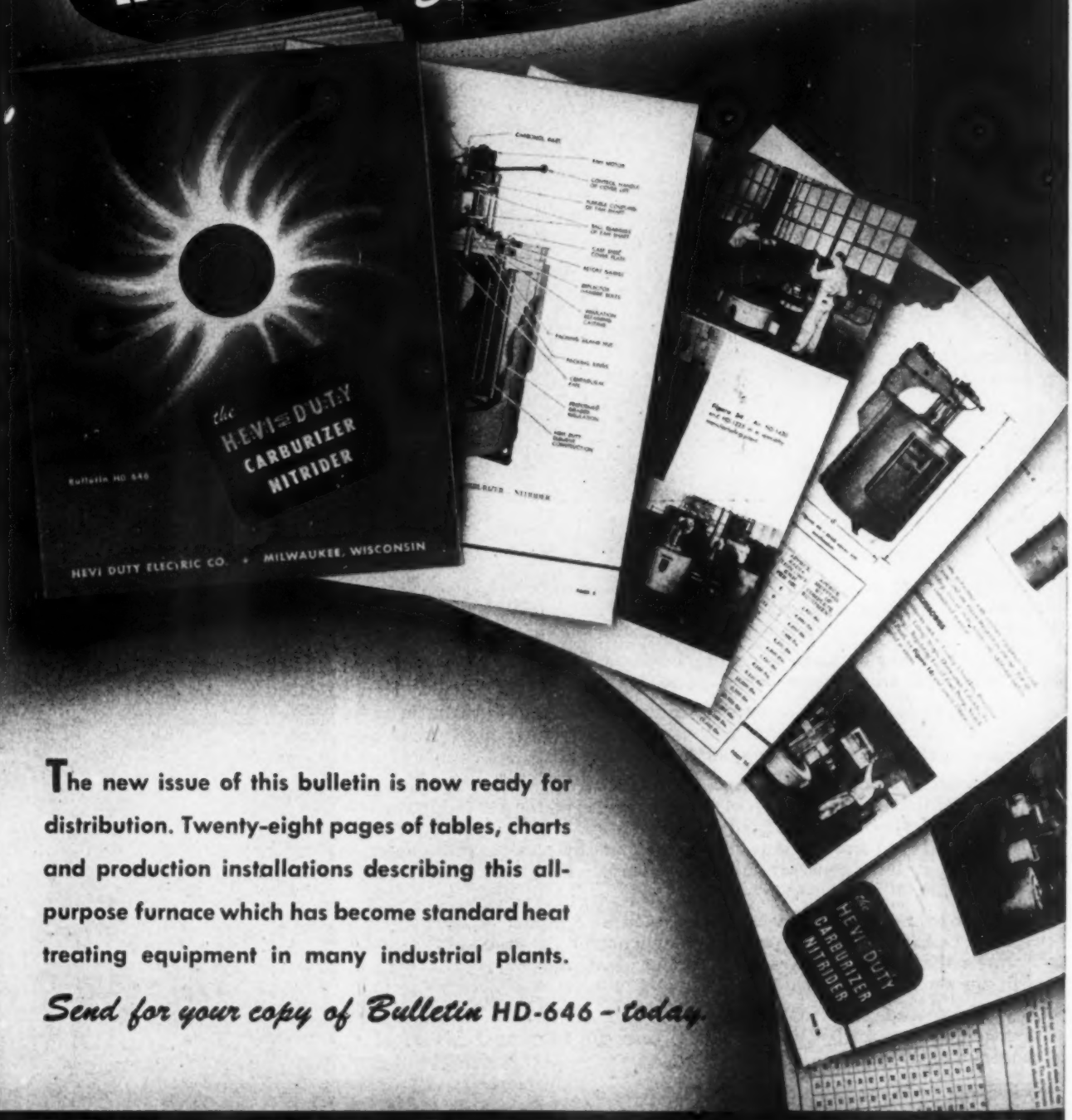
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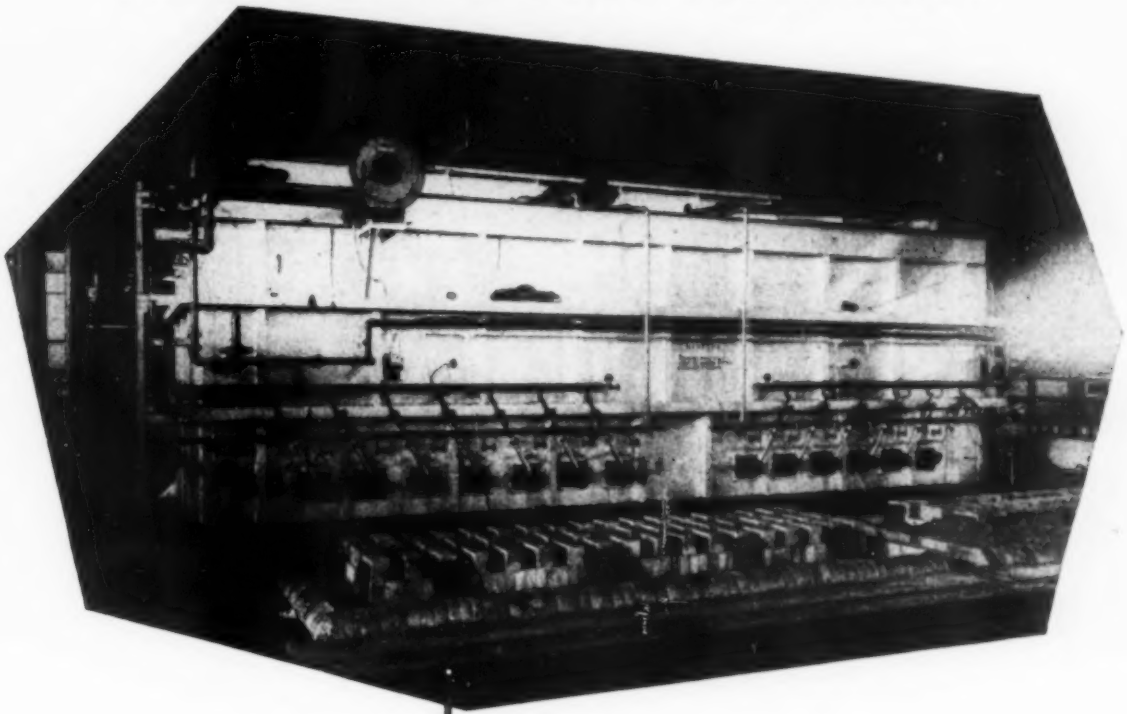

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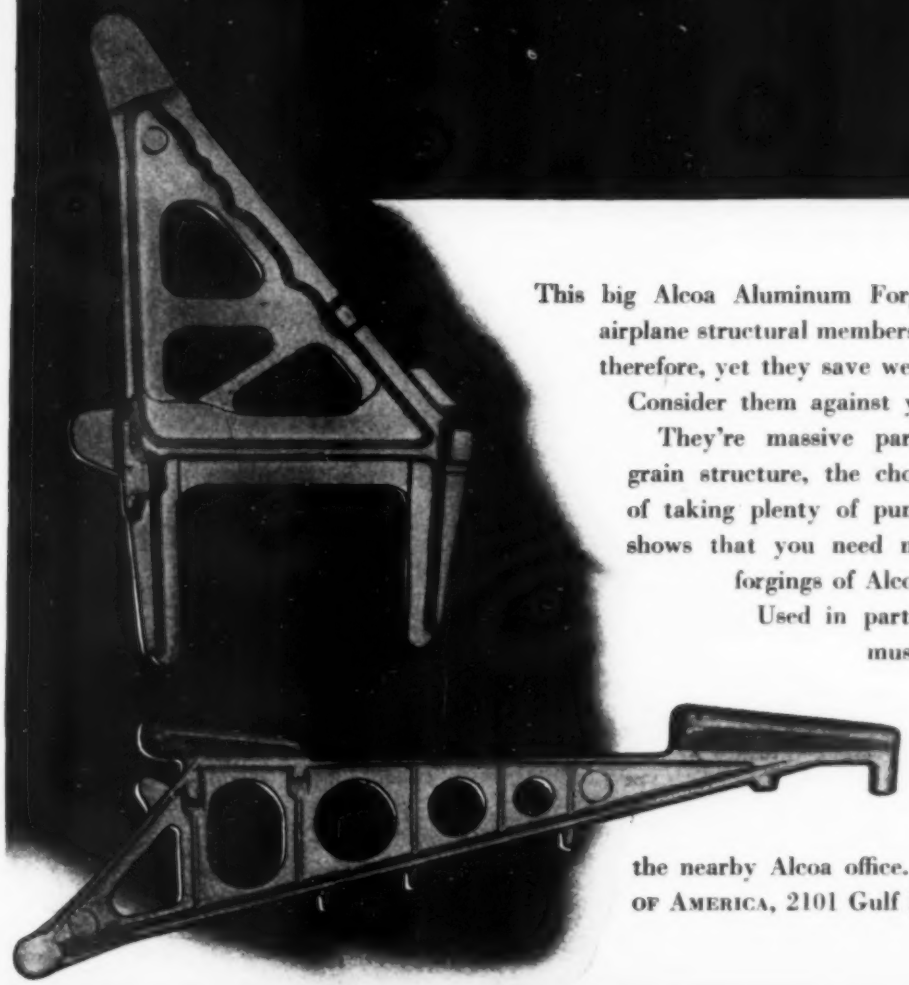

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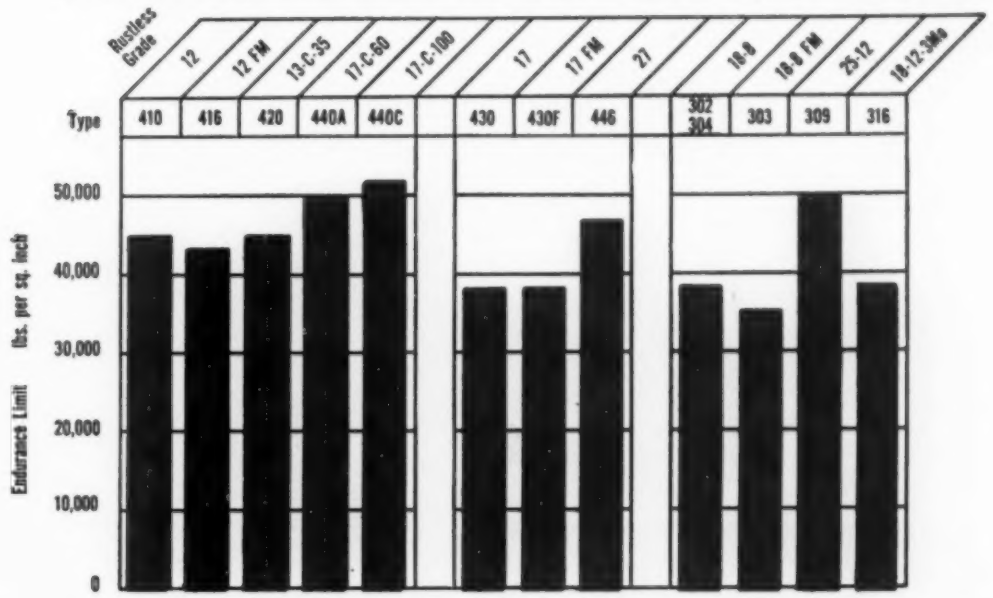

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Special "Template" Pages of furnaces, quench tanks, etc. are easily cut out—a few seconds scissor-work shows you how *your* department will *actually look.*

How do you get your copy? Write to your nearest Lindberg Engineering Company office, or to the Lindberg home office at 2448 West Hubbard St., **Chicago 12, Illinois.**

LINDBERG FURNACES

NEW EXTRUDED COATING

brings improved properties to STOODY SELF-HARDENING*

YOUR OLD FAVORITE, STOODY SELF-HARDENING, is all decked out in a new improved coating! Extruded hydraulically instead of being dipped, the new coating is much stronger, resists moisture pickup and maintains complete uniformity!

You'll notice faster welding, freedom from porosity, denser deposits. Welds with *either* AC or DC machines in any bead type!

FORGET YOUR SCALING DIFFICULTIES! Slag comes off easily while deposits are still hot—is *self-lifting* as deposits cool. Same high wear resistance as old dipped electrodes, no loss in hardness even on multiple deposits!

For many years the favorite for maximum *wear* protection—Stoody Self-Hardening is now improved for maximum *ease* of welding. Try 50 lbs. today and note the advantages! No change in price. New circulars available—see any of our 600 Stoody dealers.

STOODY COMPANY

1146 W. SLAUSON AVE. • WHITTIER, CALIFORNIA

STOODY HARD-FACING ALLOYS

Retard Wear — Save Repair

Get the most for your hard-facing dollar: Write for free "STOODY HARDFACING GUIDEBOOK"... a book by welders on hardfacing techniques.

YOUR steel requirements can best be served by a progressive, superbly staffed, completely integrated steel producer. WISCONSIN is exactly that.

Progressive is more than a word at WISCONSIN. It's a *fact* that has been demonstrated by our development of Sulfite-Treated Steel—the highly machinable steel that overcomes the faults of resulphurized steels. "H" steels of guaranteed hardenability are a specialty of ours. Both of these steels are earning wide acceptance and acclaim.

Superbly Staffed by top-flight steelmen, WISCONSIN has one prime objective: to make the best possible steel for our customers. Every man in the mill works toward that goal.

An Integrated Organization gives WISCONSIN complete control of the product from the ore mines to the customer. That control means finer steel.

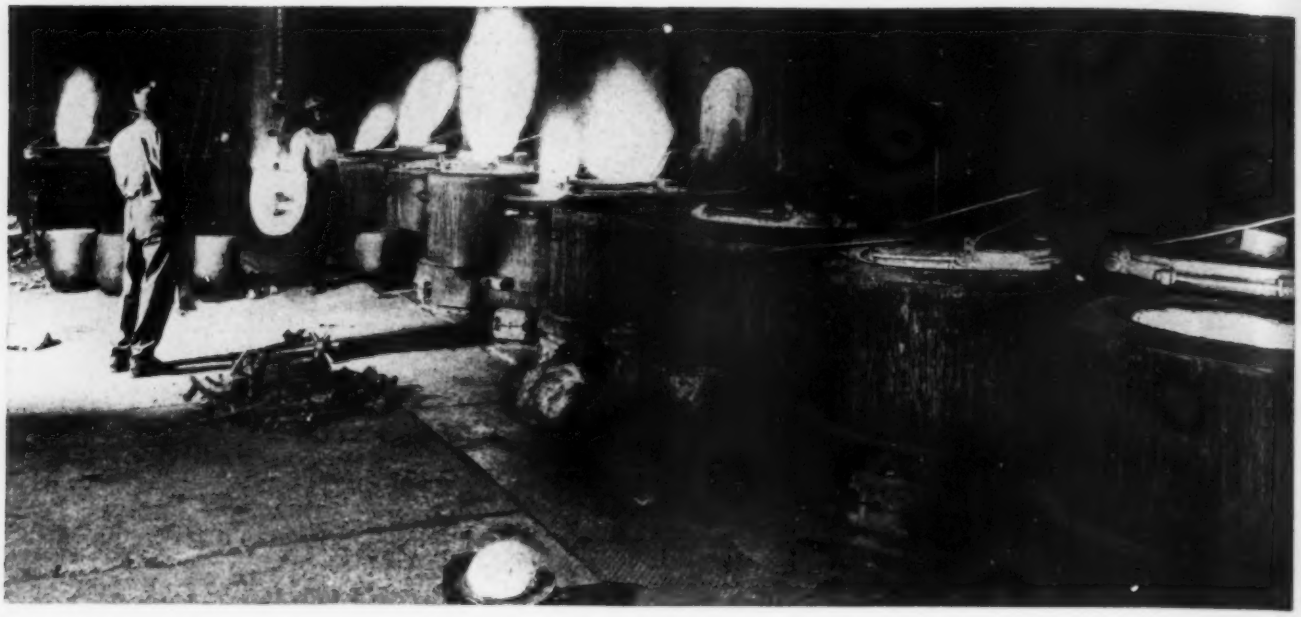
Watch WISCONSIN for steel progress. We can't supply all the steel our customers need but the picture is improving. We haven't compromised with quality. Our sales and metallurgical staffs are ready to serve you.

WISCONSIN STEEL OPERATIONS

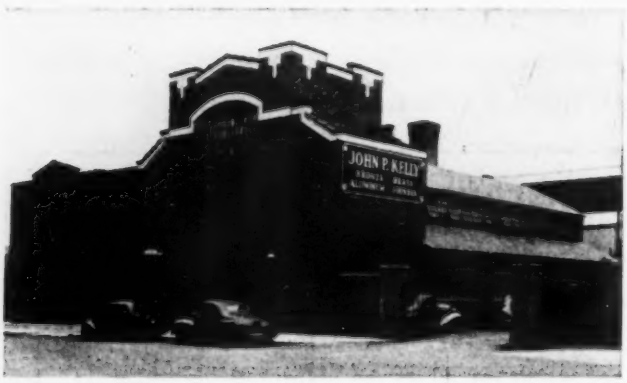
Ore Mines • Coal Mines • Ore Freighters
Blast Furnaces • Open Hearth Furnaces • Rolling Mills
Heat-Treating, Cold Finishing and Annealing Facilities

WISCONSIN STEEL COMPANY
(Affiliate of International Harvester Company)
180 North Michigan Avenue **Chicago 1, Illinois**

WISCONSIN STEEL



Large Jobbing Foundry Standardizes on CARBOFRAX Linings



John P. Kelly—Brass Founder, well known producer of high quality aluminum bronze castings, uses CARBOFRAX silicon carbide linings in all 14 of his crucible type melting furnaces. Of the Walker-York design, the furnaces are coke-fired and feature pre-heated air with controlled blast.

Quickly reviewed, his extended experience with CARBOFRAX linings shows these profit yielding results.

- Lower refractory cost per lb. of metal melted because these more durable linings last longer.
- Improved crucible life. Retaining dimensions even after much service—with choking clinker formations eliminated, CARBOFRAX linings radiate heat uniformly to the crucible.
- Steady, reliable production. As these linings do not deform under most severe operating conditions, both moderate and peak demands are fully satisfied.
- Reduced installation cost. Made accurately to size with rugged interlocking joints the CARBOFRAX blocks are quickly, easily installed.

Such advantages are made possible by the high refractoriness, excellent resistance to spalling, cracking and flame erosion and high hot strength of CARBOFRAX linings. Their distinctive characteristics make these linings equally valuable for promoting greater production at lower cost in oil and gas fired melting furnaces.

Additional information on CARBOFRAX linings for specific installations will be gladly furnished on request. Simply write Dept. N-126, The Carborundum Company, Refractories Division, Perth Amboy, New Jersey.

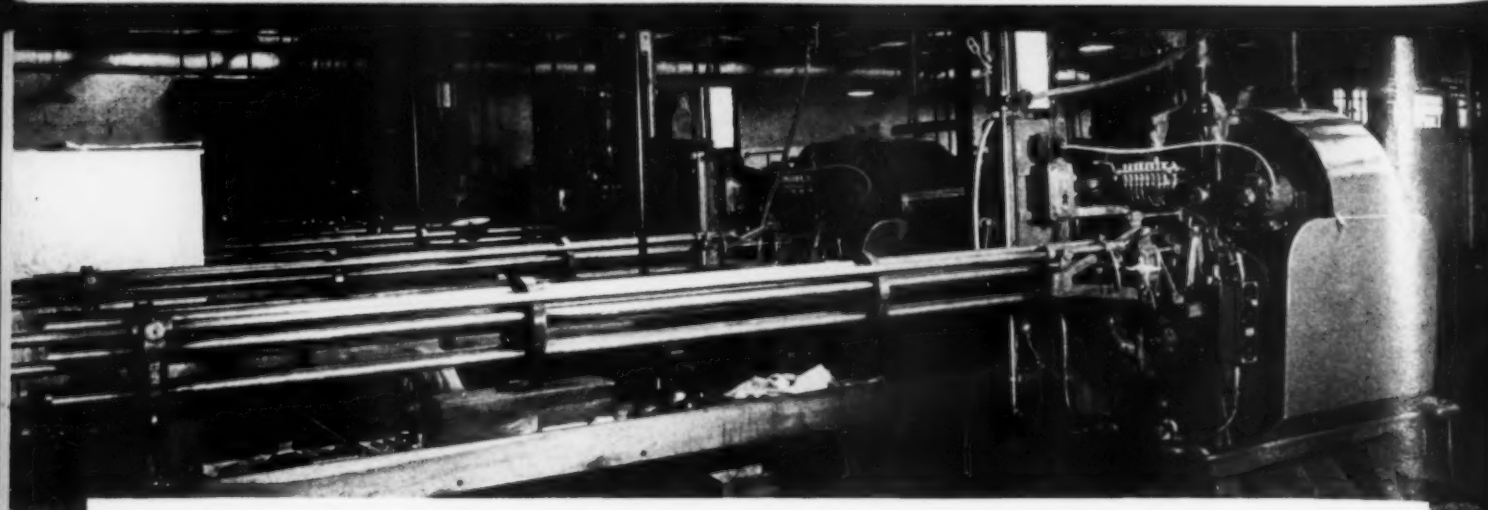
SUPER REFRACTORIES

BY CARBORUNDUM

TRADE MARK

"Carborundum" and "Carbofrax" are registered trademarks which indicate manufacture by The Carborundum Company

FREE CUTTING BRASS ROD
FOR QUICK, ECONOMICAL MACHINING
1—Special flange fitting
2—Flexible tube adapter
3—½" high-pressure fitting
4—Tapered hose connection
5—Flared-type fitting
6—Bushing for pressure tube fitting
7—Inverted S.A.E. swivel union
8—Automotive brake cylinder
9—Faucet handle
10—Flared-type fitting
11—Hot water cut-off valve
12—Oil tank cap part
13—½" I.P.S. male fitting
14—Valve stem regulator
15—Welding hose connection
16—Automotive air brake part
17—Water valve stem pack nut
18 & 19—Lamp top ornaments
20—Carbureter valve
21—Welding hose connection
22—Oil feeder valve
23—Valve stem
24—Pack nut
25—Inverted S.A.E. swivel union
26—Male swivel detachable union
27—Flared-type fitting
28—Detachable ring-type hose fitting
29—Compression fitting assembly
30—Oil feeder adjusting valve
31—7/16" female compression union
32—Fuse part
33—S.A.E. long nut
34—Orifice spud
35—Worm gear
36—Threaded sleeve-type union
37—Toilet tank spud
38—Acorn nuts for finish trim
39—Hex nuts



Facts about REVERE FREE CUTTING BRASS ROD

Lead Content. Revere Free Cutting Brass Rod contains about 3% lead. This is not dissolved but is thoroughly distributed throughout the metal in the form of finely-divided particles. The lead reduces friction by causing the chips to break off short, so that they are in only momentary contact with the cutting edge of the tool. This lessens the amount of heat generated. Life of the tool is correspondingly extended, and long runs without regrinding are usual.

Machining Speeds. Surface speeds as high as 700 feet per minute are possible. Rough cuts as deep as 0.020" can be taken. Such speeds and cuts materially reduce production time over other materials having less outstanding machining characteristics.

Finish. With proper tooling, parts made of Revere Free Cutting Brass Rod come from the machine with a brilliant, smooth, highly-polished appearance, due to the practically flawless surface. Any tolerance within the capability of the machine and operator may be easily obtained. Threads are sharp and clean down to their roots.

No Burrs. This metal may be cut- and roll-threaded, drilled and tapped, milled, broached, and sawed with no appreciable burrs.

Temper. In the majority of cases, Revere Free Cutting Brass Rod is supplied hard drawn. This hardness facilitates chip breakage, while the high strength resulting from drawing assures strong threads. However, if desired for special purposes, Revere can supply soft Free Cutting Brass Rod.

High Standards. Revere Free Cutting Brass Rod is drawn to close tolerances on dimensions and straightness, and is stress-relieved after drawing. The metallurgical and physical characteristics of the metal are under constant laboratory check. It is therefore especially suitable for automatic screw machines, which require stock having high uniformity in quality and dimensions.

Additional Advantages. The smooth surfaces produced by machining Revere Free Cutting Brass Rod are ideal for plating. The metal is easily soldered, can be welded if desired, and it is of course non-rusting and corrosion-resistant. Even at a slightly higher cost over other materials, this brass often is more economical for screw machine production, due to the speed with which the various operations may be conducted, and the value of the scrap.

Consult Revere. Because no single metal or alloy is suitable for all requirements, Revere offers many, each having some outstanding virtues and advantages. Selection of the most advantageous Revere Metal for a given process, part, or product may make a big improvement in such important items as cost of manufacture, durability, and even saleability. The Revere Technical Advisory Service will gladly cooperate with you in studying your requirements.

TYPICAL PROPERTIES

REVERE
FREE CUTTING BRASS ROD
Alloy No. 240

COMPOSITION
Copper 61.5%
Zinc 35.5
Lead 3.0

TENSILE STRENGTH
Hard* 65,000 pounds per square inch
Soft† 50,000

ELONGATION
% in 2 inches
Hard* 15
Soft† 50

DENSITY
0.307 lbs. per cubic inch

COEFFICIENT OF EXPANSION
.0000113 per °F (*at* 68° F

ELECTRICAL CONDUCTIVITY
28.6 (% I.A.C.S. (*at* 68° F)

THERMAL CONDUCTIVITY
73 Btu. per sq. ft. per ft. per hr. per °F (*at* 68° F

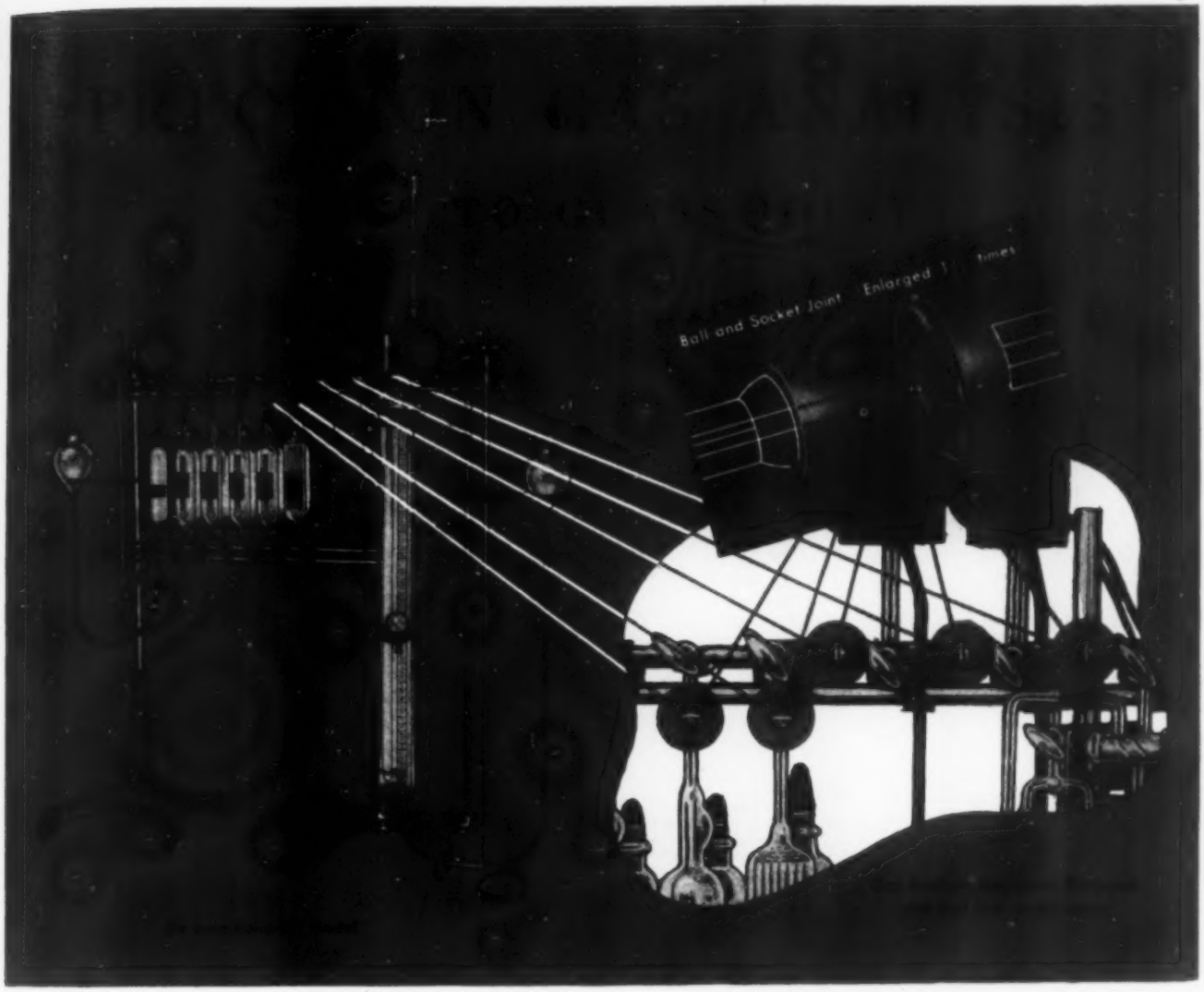
*Hard, Rockwell B72 (app.)
†Soft, Rockwell F65 (app.)

Revere Metals include: *Copper and Copper Alloys:* Sheet and Plate, Roll and Strip, Rod and Bar, Tube and Pipe, Extruded Shapes. Forgings; *Aluminum Alloys:* Tube, Extruded Shapes, Forgings; *Magnesium Alloys:* Sheet and Plate, Rod and Bar, Tube, Extruded Shapes, Forgings; *Steel:* Electric Welded Steel Tube.

REVERE
COPPER AND BRASS INCORPORATED
Founded by Paul Revere in 1801
230 Park Avenue, New York 17, New York
Mills: Baltimore, Md.; Chicago, Ill.; Detroit, Mich.; New Bedford, Mass.; Rome, N. Y.— Sales Offices in Principal Cities, Distributors Everywhere.

• • •

Listen to *Exploring the Unknown* on the Mutual Network every Sunday evening, 9 to 9:30 p.m., EST.



BURRELL BALL AND SOCKET JOINTS ELIMINATE RUBBER TUBING AND PROVIDE TIGHT FLEXIBLE CONNECTIONS

CONVENTIONAL design in gas analysis apparatus specifies rubber tubing connections between the various glass parts. While suitable for most purposes, the rubber joint has disadvantages which can be overcome only through the use of solidly sealed assemblies without joints, or through the use of a flexible type of ground joint such as the ball and socket. The straight taper joint has not been popular because of its rigidity and consequent likelihood of easy breakage.

The ball and socket joint offers a simple means of eliminating rubber connections and is recommended for consideration where:

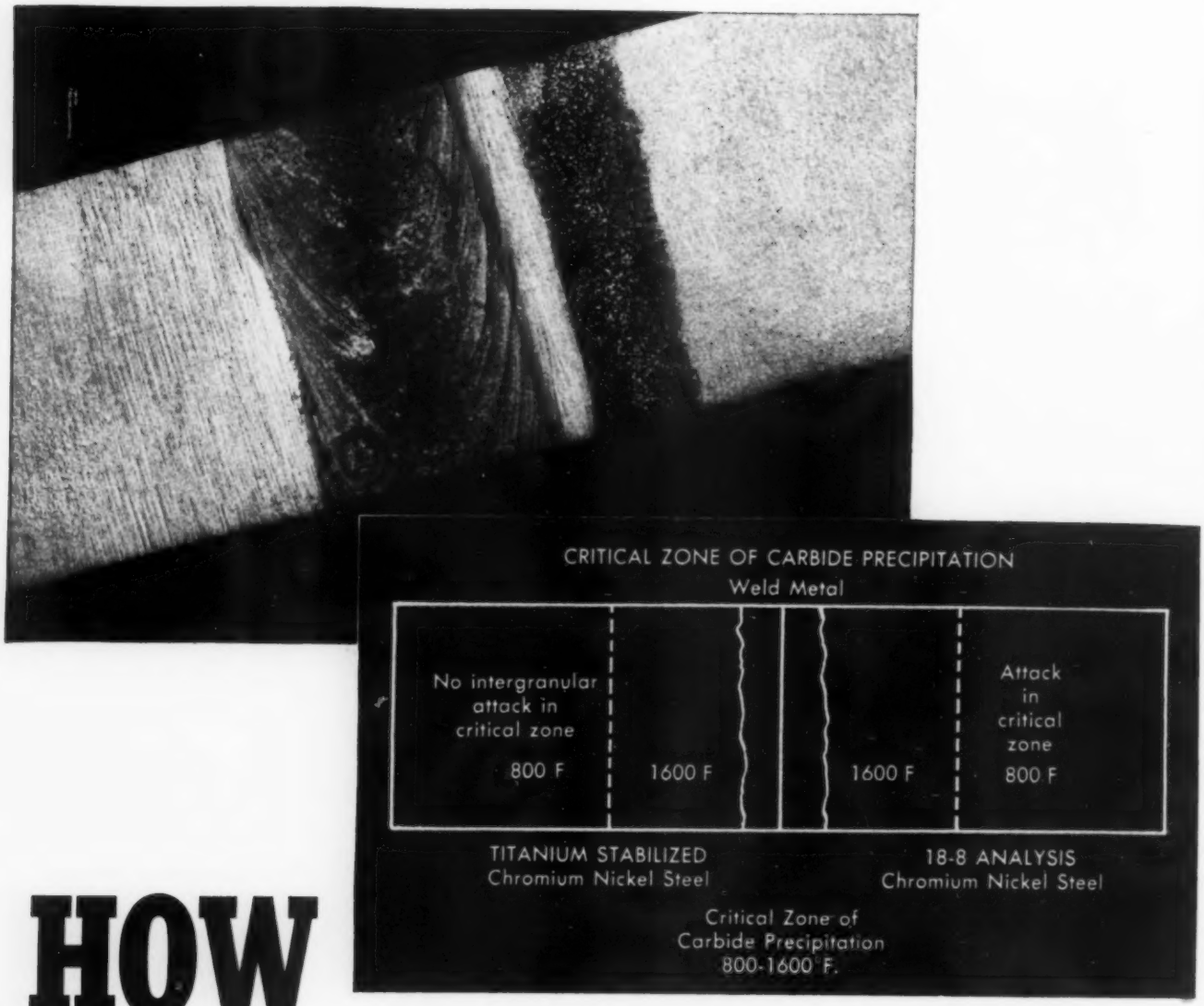
—the gas sample should be kept out of contact with rubber as when substantial portions of heavy hydrocarbons are present.

—the small amounts of gas trapped at times between the butted ends of the glass connections may be of significance.

—convenience only is the deciding factor.

Burrell will furnish ball and socket joints on any Build-Up gas analysis assembly if so ordered. On this, or any other special application, consult the Burrell Engineering Department. BURRELL TECHNICAL SUPPLY CO., 1936-42 Fifth Ave., Pittsburgh 19, Pennsylvania.

SCIENTIFIC APPARATUS
BURRELL
LABORATORY CHEMICALS



HOW

Titanium Prevents Intergranular Corrosion in Welding Stainless

In the welding of austenitic stainless steels, the retention of carbides in solution is not possible because the resulting heating between 800 and 1600°F. precipitates the carbon present as chromium carbides in an intergranular pattern. In this condition the zones near the welds are predisposed to intergranular corrosion in certain media.

Titanium, the stabilizing element, prevents precipitation of chromium carbide in an intergranular pattern by virtue of the fact that it has greater affinity for carbon than any other element has for carbon, and accordingly, the carbides of titanium are uniformly dispersed thereby preventing intergranular precipitation and corresponding intergranular corrosion.

TAM

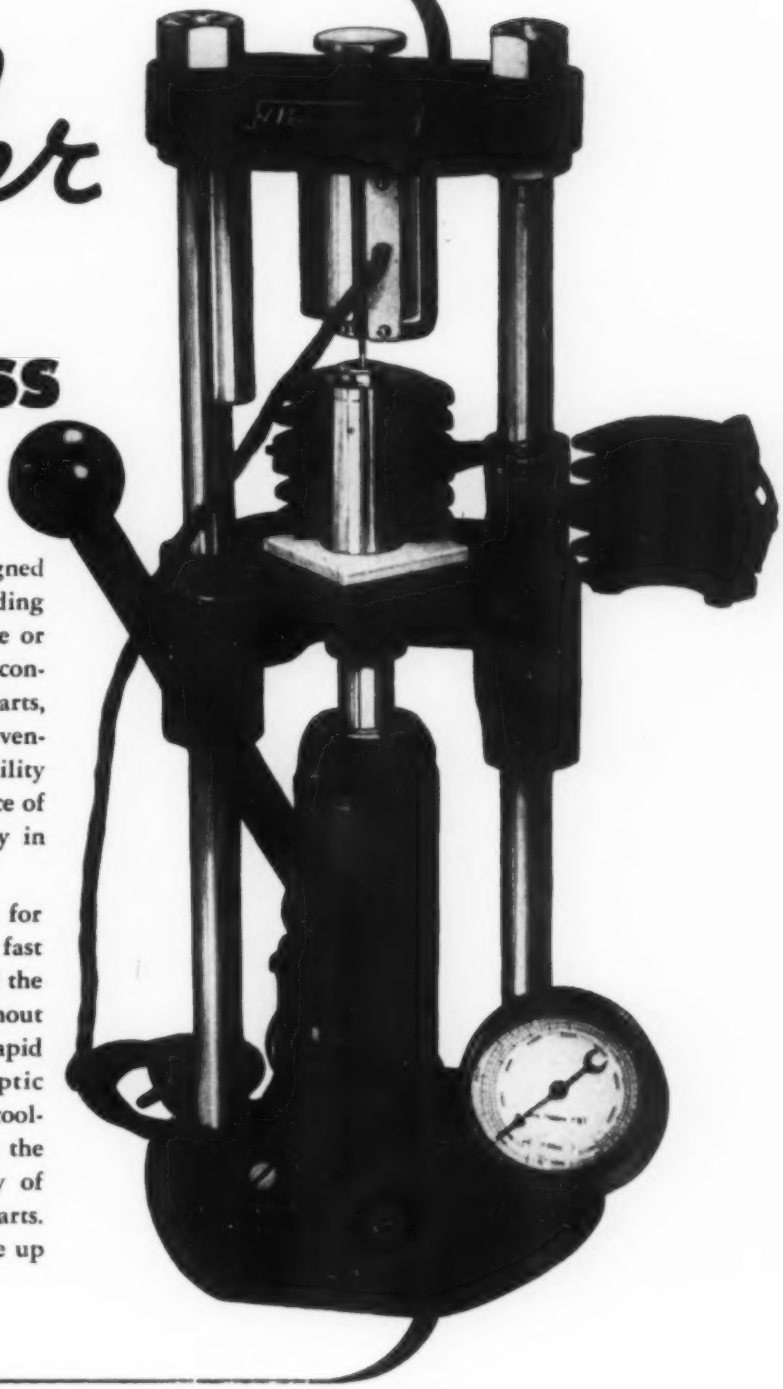
TITANIUM ALLOY MANUFACTURING COMPANY

Executive Offices: 111 Broadway, New York City *General Offices and Works:* Niagara Falls, N. Y.

Buehler

SPECIMEN MOUNT PRESS

No. 1315



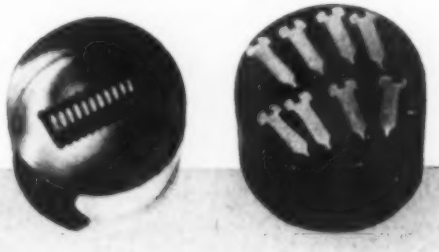
This new, improved model is designed specifically for the rapid precision molding of specimen mounts, either in bakelite or transparent plastic. The simple, rugged construction, without concealed working parts, offers maximum accessibility and convenience for the operator. This accessibility combined with the smooth performance of this press, permits speed and accuracy in molding specimen mounts.

Molding tools are lapped finished for close tolerance with a perfect fit. The fast working solid heater can be raised and the cooling blocks swung into position without releasing pressure on the mold. This rapid cooling permits removal of transoptic mounts in a few minutes. Heater and cooling blocks need not be removed from the press thus eliminating the possibility of accidental burns in handling these parts. This model press will develop pressure up to 10,000 lbs.

THE BUEHLER line of specimen preparation equipment includes . . . .
CUT-OFF MACHINES • SPECIMEN MOUNT PRESSES • POWER GRINDERS • EMERY PAPER GRINDERS • HAND GRINDERS • BELT SURFACERS • POLISHERS • POLISHING CLOTHS • POLISHING ABRASIVES

Buehler Ltd.

A PARTNERSHIP



METALLURGICAL APPARATUS

165 West Wacker Drive, Chicago 1, Illinois

HERE'S HOW YOU CAN...

IMPROVE QUALITY
INCREASE PRODUCTION
CUT PRODUCTION COSTS

with General Electric Industrial X-Ray Units

The experience of hundreds of satisfied users provides concrete evidence that G-E X-Ray Industrial Units pay real dividends—both scientific and economic.

One of the nation's leading producers of heavy steel castings has collected tangible dividends from its investment in a G-E X-Ray million-volt unit. Here are the facts:

IMPROVED QUALITY

Detection of internal defects in castings is by no means the sole advantage of x-ray inspection. Routine radiographic examination of intricate castings is employed to inspect areas which may be highly stressed in service. Castings so inspected may be used with complete confidence for service in fields where higher stresses are encountered.

CUT PRODUCTION COSTS

With day-to-day precision production control, if changes are indicated they may be made quickly and accurately without the costly sectioning of one casting. In instances where repair welding is necessary, a rapid radiographic survey of the area in question reassures both the foundryman and the customer that an adequate amount of metal has been removed and the welding properly done.

INCREASED PRODUCTION

Radiography with the 1000 kv unit provides a rapid, non-destructive check on the soundness of production castings and permits the inspection of a larger percentage of the product than would otherwise be possible. Such production control enables the foundryman to verify his molding technic on a day-to-day basis.

THESE BENEFITS CAN BE YOURS

No matter what you manufacture. They are not restricted to the G-E X-Ray million-volt unit. They are available with every G-E X-Ray industrial unit and G-E X-Ray provides a full line of industrial x-ray units having a voltage range and mounting structure best suited to your particular problem.

TO GET FULL INFORMATION

If you're interested in improving quality, increasing production and cutting production costs, you owe it to yourself and to your company to investigate G-E X-Ray's industrial units. For complete information—without cost or obligation—call in G-E X-Ray's experienced industrial engineers. Their services are yours for the asking. Write or wire General Electric X-Ray Corporation, 175 West Jackson Blvd., Chicago 4, Illinois. Address Dept. 2519.

GENERAL ELECTRIC X-RAY CORPORATION

GAS

supplies

THE PRODUCTIVE FLAMES OF INDUSTRY

for

The *productive flames of industry* perform countless other duties. Practically every industrial heating requirement is a logical task for GAS, the versatile fuel, and for modern Gas-fired equipment.

FLEXIBILITY—CONTROLLABILITY—SPEED—UNIFORMITY—ECONOMY; wherever these qualities are required in process-heating, the dependable fuel is GAS. Inherent features of this fuel will suggest many additional industrial applications.

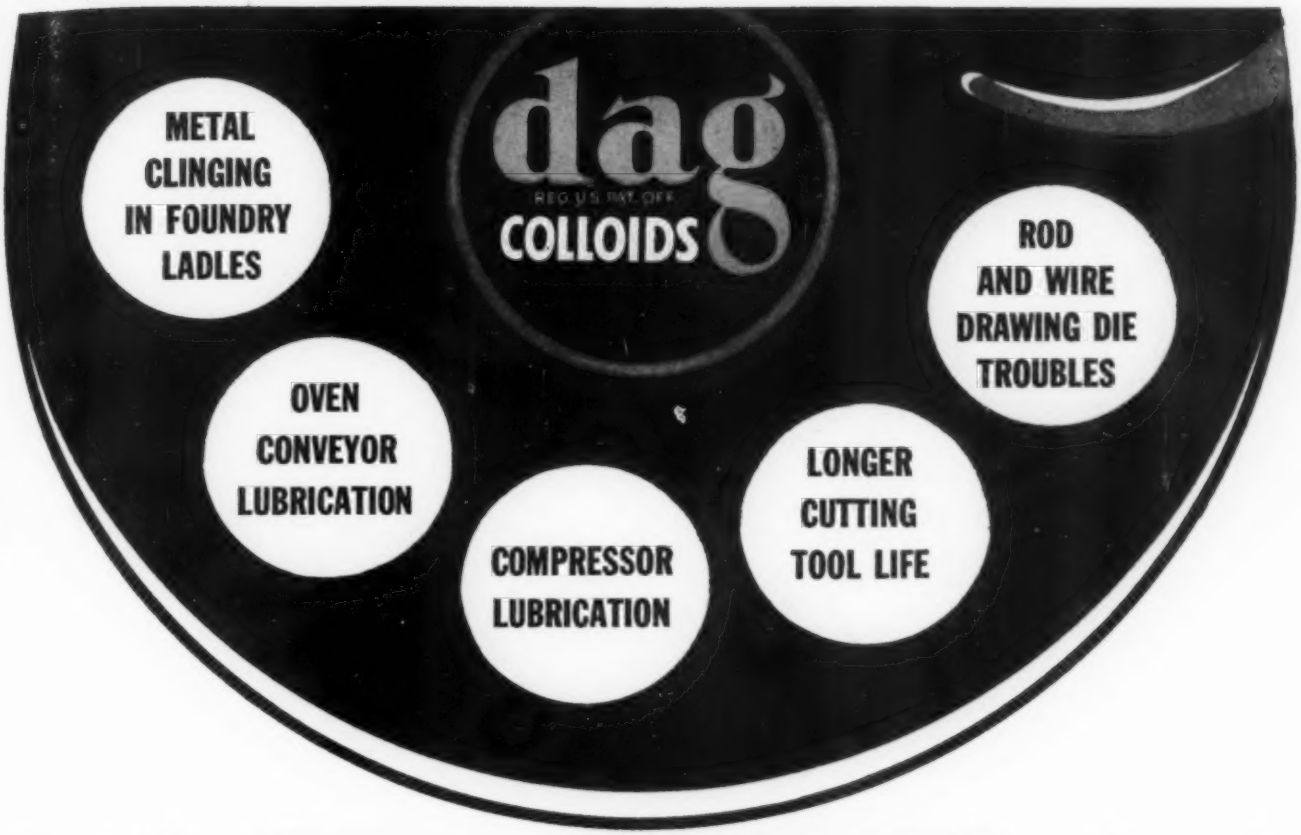
Day by day, successful applications of GAS eliminate production snarls in hundreds of manufacturing plants. Year after year, engineers and production managers specify GAS for increasing numbers of industrial heating installations. More and more the *"Trend is to GAS"* for all industrial heating.

Your local Gas Company solves industrial heating problems every day. Results of these studies will be helpful to you, too. An experienced Industrial Representative will recommend the proper use of GAS for your production process.

- core baking
- heat treating
- spheroidizing
- batch melting
- moisture control
- continuous copper brazing
- controlled atmosphere processing
- powder metal sintering

AMERICAN GAS ASSOCIATION

420 LEXINGTON AVENUE, NEW YORK 17, N.Y.



Put the "finger" on PROBLEMS like these!

How?—by selecting and applying the *right* **"dag"** dispersion for each job. And it's as simple as it sounds except for one fact: while most engineers and plant men do know what **"dag"** colloidal graphite is, many of them are unaware of *all* the dispersions available or *all* the diverse industrial applications for which they are designed.

Actually there are seventeen **"dag"** suspensions, in carriers as diverse as water, oils, alcohol and volatile hydrocarbons. Each possesses not only the many unique properties of graphite itself (in what amounts to true liquid form) but also the valuable special characteristics of its liquid carrier. As a consequence, uses are much more numerous than is generally known.

And that's just why the booklets listed below have been compiled—to tell the men who need to know exactly *how*, exactly *why* and exactly *where* **"dag"** colloidal graphite dispersions can profitably assist in specific industrial operations.

They're free, of course, and are mailed to you without obligation as part of Acheson Colloids' broad service activities.

ACHESON COLLOIDS CORPORATION
PORT HURON, MICHIGAN

This new literature on "dag" colloidal graphite is yours for the asking:

- **460** — A data and reference booklet regarding "dag" colloidal graphite dispersions and their applications. 16 pages profusely illustrated.
- **421** — Facts about "dag" colloidal graphite for ASSEMBLING AND RUNNING-IN ENGINES AND MACHINERY.
- **422** — Facts about "dag" colloidal graphite as a PARTING COMPOUND.
- **423** — Facts about "dag" colloidal graphite as a HIGH TEMPERATURE LUBRICANT.
- **431** — Facts about "dag" colloidal graphite for IMPREGNATION AND SURFACE-COATINGS.
- **432** — Facts about "dag" colloidal graphite in the FIELD OF ELECTRONICS.

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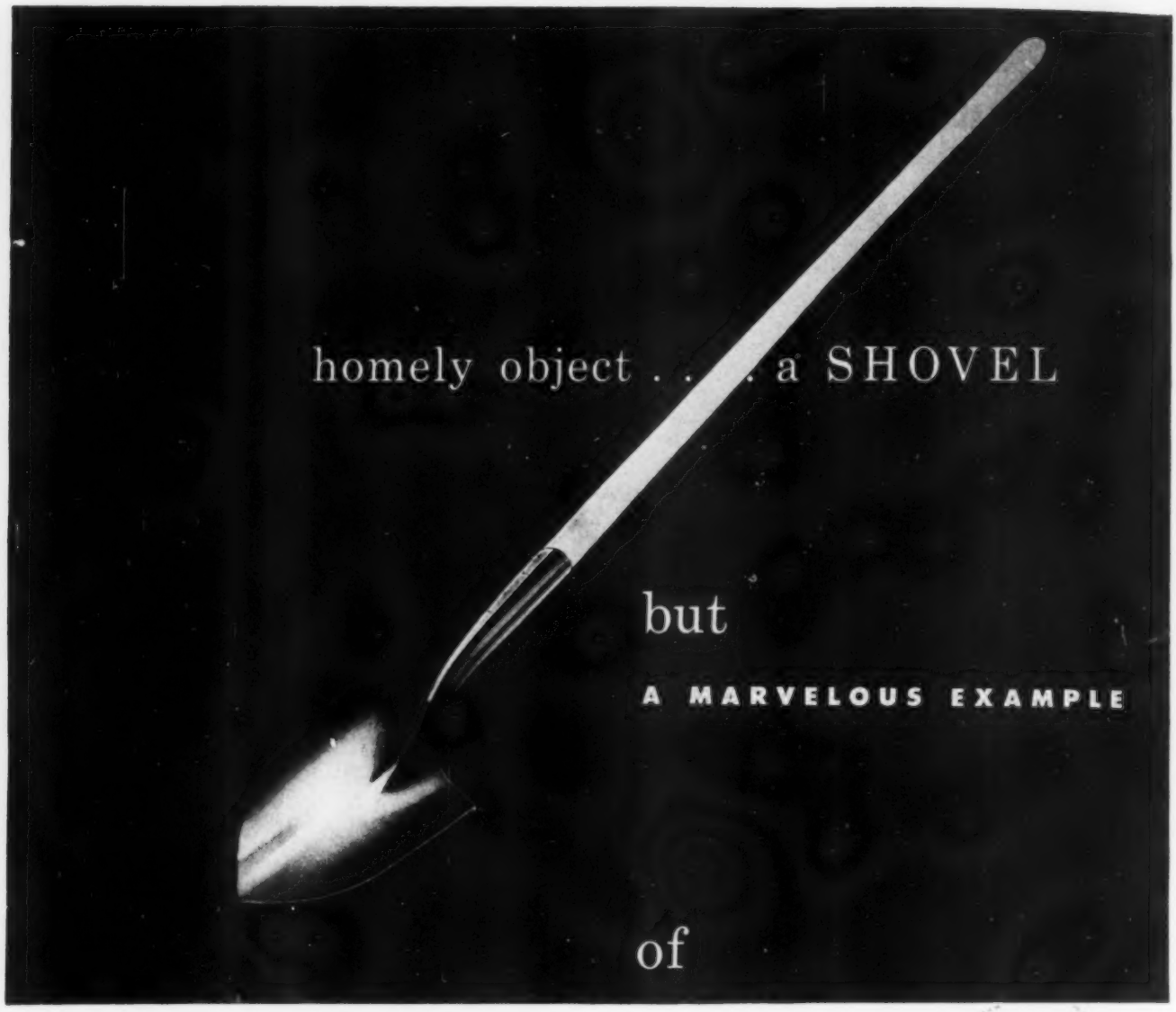
Please send me without obligation, a copy of each of the bulletins checked.

460 ☐ NAME_____
421 ☐ POSITION_____
422 ☐ FIRM_____
ADDRESS_____
423 ☐ CITY_____ ZONE_____ STATE_____
431 ☐ OUR PRESENT OIL SUPPLIER IS_____
(Lubricants containing **"dag"** colloidal graphite are available from major oil companies.)
432 ☐



WHAT MOLYBDENUM DOES FOR STEEL

For rough and tough uses, the durability of some objects of modern manufacture is incredible, even when you see it demonstrated. A truck tire, for example. Or a supremely good shovel. How could there be anything so robust and defiant of hard usage —so nearly indestructible? Yet there it is!

In any such case there must be some key factor or singular ingredient to account for the demonstration. In shovels, it's Molybdenum. Judiciously used, at very little added cost, it causes them to "outwear and outlast" any others, wherever and however made—so says the bold challenge of the manufacturer.

Larger and more diversified use of alloying materials, for heavy mechanical and structural purposes as well as for highly specialized and technical ones, has been justified by recent experience.

The Molybdenum Corporation, as a supplier of Molybdenum, Tungsten, and other alloying materials, has prepared informative literature and is glad to be consulted by any user.

AMERICAN Production, American Distribution, American Control, Completely Integrated.

Offices: Pittsburgh, New York, Chicago, Cleveland, Detroit, Los Angeles, San Francisco, Seattle.

Sales Representatives: Edgar L. Fink, Detroit; Bromley-Donaldson Co., Los Angeles, San Francisco, Seattle.

Subsidiaries: Cleveland-Tungsten, Inc., Cleveland, O.; General Tungsten Manufacturing Co., Inc., Union City, N. J.

Works: Washington, Pa.; York, Pa.

Mines: Questa, New Mexico; Yucca, Ariz.; Urad, Colorado.

MOLYBDENUM **CORPORATION OF AMERICA**
GRANT BUILDING PITTSBURGH, PA.

MCA

Are You Wrestling with Manufacturing Problems? You Can Get *More* Products per Ton—*Better* Products per Ton—with N-A-X HIGH-TENSILE Steel

Manufacturing experience proves it true: N-A-X HIGH-TENSILE steel enables the average user of hot- and cold-rolled sheets to increase production of units 33% *without* increasing steel consumption.

With this low-alloy, high-tensile steel, less metal is required for each unit. Sections are thinner, yet have *equal* strength and *greater* durability. This saving may well make it possible for you to produce four parts where you normally produce three.

N-A-X HIGH-TENSILE steel can be drawn and formed to intricate shapes. It has excellent weldability, high fatigue- and corrosion-resistance and great impact toughness. These superior qualities bring you not only a better product—but also important economies in handling, fabricating and finishing.

MAKE A TON OF SHEET STEEL GO FARTHER
Specify—
N-A-X
HIGH-TENSILE STEEL

COPYRIGHT 1946
GREAT LAKES STEEL CORP.

The full extent to which N-A-X HIGH-TENSILE can increase and improve your production depends, of course, on your own particular products and methods. Our metallurgists and engineers will be glad to help you investigate fully.

GREAT LAKES STEEL
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N-A-X ALLOY DIVISION • DETROIT 18, MICHIGAN
UNIT OF NATIONAL STEEL CORPORATION

Advertisement

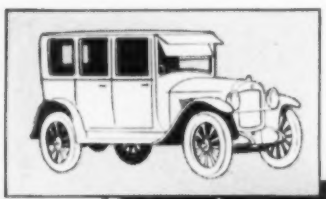
DECEMBER, 1946

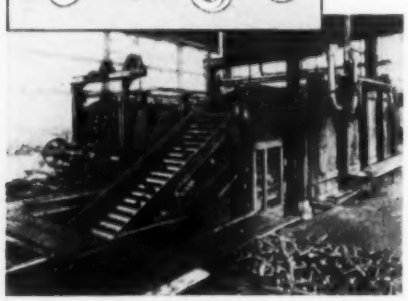
R-S FURNACE FACTS

ISSUED MONTHLY BY R-S PRODUCTS CORPORATION, PHILADELPHIA 44, PA., FOR THOSE CONCERNED WITH QUALITY HEATING OF METALS

23 Years Ago...an R-S "First" which Started an Era

Old hands in the American Society for Metals (then called the Steel Treaters) will remember this particularly famous group of 1923 furnaces. The Bureau of Mines took movies of them; "Mike" Watson, metallurgist for the user company (American Gear & Mfg. Div. of Hupp Motors) toured ASM chapters and technical colleges giving speeches about them; and Professor Trinks wrote the details of their design into his now-famous





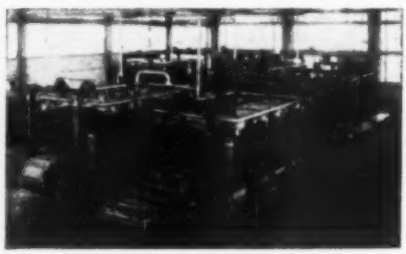
texts (see, Industrial Furnaces, Vol. II, 2nd ed., Figs. 250, 253, 256 and 279).

Why so famous?

Well, Sir, this family of four R-S furnaces made up *the very first continuous, automatic heat treating line for automotive parts*—and started the era of production-line heat treating we know today.

Here's the job they did. They took an endless stream of Hupmobile steering-knuckles and axle forgings through the harden-quench-and-draw cycle by fully mechanized means. The axle hardening furnace was an early walking-beam type. Other units in the line employed chain-conveyor and continuous-belt handling. All were oil fired. Temperature control was automatic. In fact, so young was automatic temperature control in 1923 that R-S had to build the control valve itself—one of the first such valves.

Our point is this! R-S has been around for a long time—with progressive, but practical, design sense of the brand that



makes improved production ideas work.

And if you study the photos closely, you'll see that the same principles of construction (geared door hoists, chain take-ups, ample expansion provisions, etc.) which characterize good furnace design today, characterized R-S methods 'way back in the early days of 1923.

ON BUYING FACTORY-BUILT FURNACES

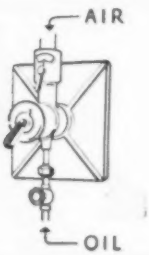
A furnace not built on your premises
May become, without warning, a nemesis.
Hidden faults of erection
May pass your inspection,
And assert themselves later—with emphasis.

But buy it, instead, from R-S,
And its "insides" you won't have to guess.
You can kibitz the making;
See the care we are taking
To keep year-round maintenance less.

Furnace men seem to like limericks that have to do with the business. Since starting to print them this Fall (see the October and November FURNACE FACTS), we find that there are several "bards-of-the-craft". If you're limerick-looney too, send in your contributions. We'll print them.

Tip on Oil Burner Piping

Be sure that oil branch lines approach burners *from below*. Let the air lines come down from above. Then, if shut-off valves leak or jam, drainage is in the right direction. Imagine what could happen when you light your furnace after oil has leaked *into* the furnace chamber during periods of shut-down.



It's details like this which have earned the respect the R-S nameplate enjoys.

...and Here's the Man Who Designed Them

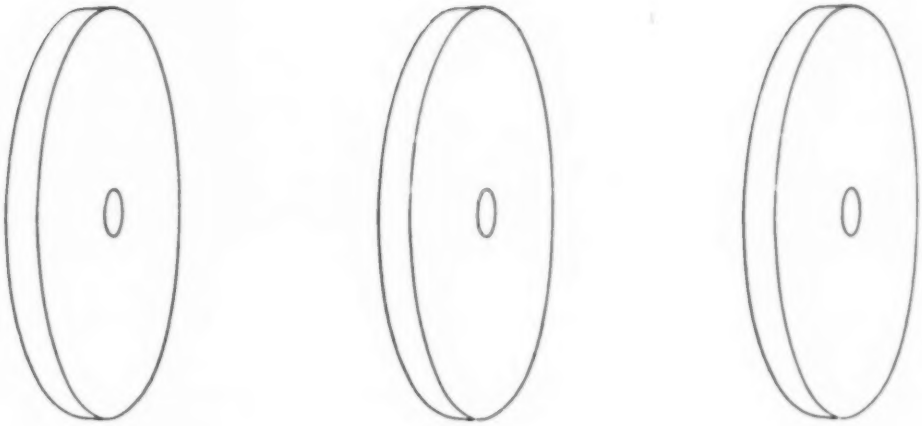
Meet our own vice president and chief engineer, D. E. Wyman, who designed

the Hupp axle and knuckle furnaces which started the era of continuous sequence heat treatment above discussed.

For those who don't yet know Mr. Wyman, despite 33 years in industrial furnace design, it will be worth noting that, in addition to being the father of the famous Hupp harden-quench-and-draw lines of 1923, he designed the Navy's first ordnance furnaces at Pearl Harbor; led the R-S engineering crew during two world wars; is an authority on rotary, pusher and conveyor furnace construction; knows how products behave under heat (from copper spark-plug gaskets in the annealing range to forging ingots at 2300°F or hundred-ton weldments being stress relieved); and has done outstanding development work on materials handling mechanisms for high temperature service.

Since 1913 he's been active at metalmen's meetings and furnace-men's round-ups—but mostly he's home at R-S in Philadelphia working for you—making good furnaces better.

JML co P-M



C-GRADE H-GRADE R-GRADE

There's more to grinding grades than the A, B, C's

The A, B, C's which appear as identification on a grinding wheel help simplify proper grade selection. By clearly showing relative hardness, they make your choice quicker, easier...aid in assuring the right grade for the job. That's one reason wheels by CARBORUNDUM are plainly marked. But, there's more to it than the old chestnut, "the softer the metal, the harder the wheel." It's not that easy.

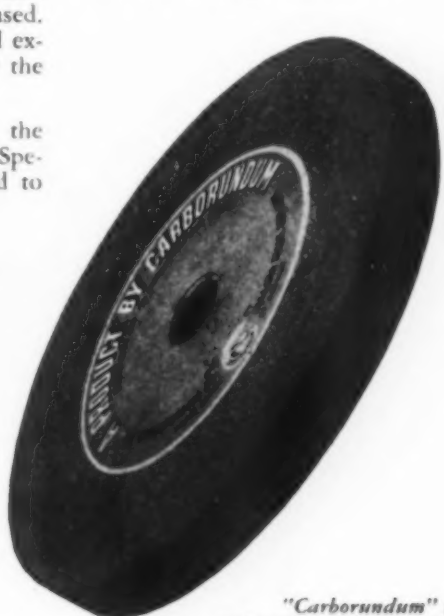
You realize, for instance, that wheel speeditself affects grinding action. The same grade reacts differently at various speeds. The condition of the machine and the amount of vibration can make a difference. Desired finish...required tolerance must be considered. Coolant conditions vary. The actual type of operation—snagging, surfacing, internal grinding or whatever it is—influences practical selection.

Yes—there are many important factors to check before you can be sure of the right grade designation for the job.

That's why we suggest consulting your CARBORUNDUM salesman or our distributor's representative. These men work throughout the year on a wide variety of grinding problems. They are familiar with grinding in production... in tool rooms...wherever it is used. They have practical knowledge and experience to help you pick exactly the wheel you need for the job.

Assisting these representatives in the field are our Abrasive Engineers. Specialized experts, they are equipped to analyze uncommon problems...recommend sound solutions. And, here in our modern laboratories are scientists and technicians who are working on the application of abrasive developments to changing grinding practices.

This *three way route* to better grinding is easy to use. No obligations are incurred. Merely talk "grinding" with a CARBORUNDUM representative. He'll be glad to assist you. The Carborundum Company, Niagara Falls, N. Y.



A good rule for good grinding . . . **CALL IN**

CARBORUNDUM

TRADE MARK

ABRASIVE WHEELS

Silicon Carbide
Aluminum Oxide
Diamond

COATED AND BONDED ABRASIVES

Paper and Cloth Combinations
Sheets, Rolls, Discs
Cylinder Hones
Sticks, Stones & Rubs
Specialties

ABRASIVE GRAINS AND COMPOUNDS

for:
Polishing
Lapping
Pressure Blasting
Finishing

"Carborundum" is a registered trademark which indicates manufacture by The Carborundum Company

Inspection with MAGNAFLUX*

Protects Prestige . . . and PROFITS

● To meet the challenge of keener competition . . . to successfully combat soaring production costs . . . make Magnaflux your first line of defense. Inspection with Magnaflux of parts cast, forged, or machined of ferrous metal assures a product that's *right*—with the *right* profit for you.

Quickly, accurately and economically, Magnaflux locates the major causes of trouble—shrinkage cracks, blow holes, porosity and many other surface and sub-surface defects—exposes these threats to customer goodwill *before* they are found through failure. Equally important, Magnaflux eliminates wasting time and labor on costly machining of unsound components.

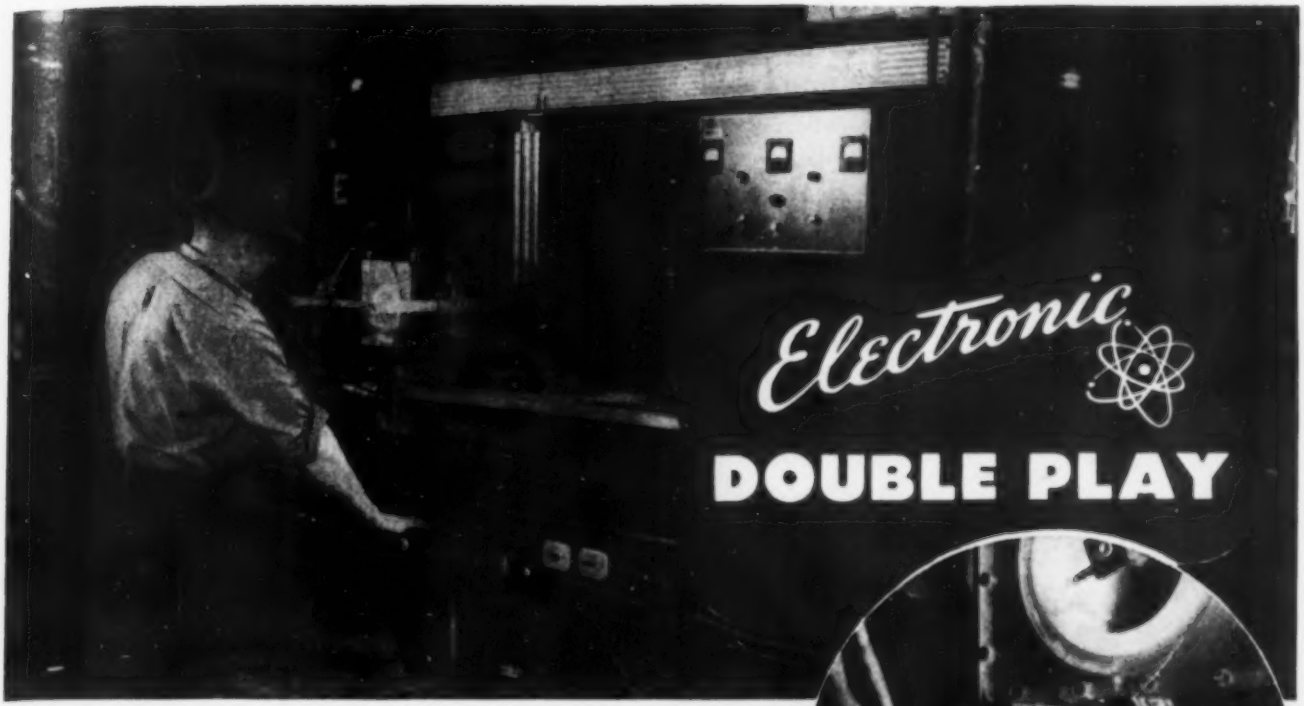
Now, more than ever, your successful operation calls for the *positive* quality control assured by non-destructive Magnaflux . . . *Write today for full details.*

* *Magnaflux, Reg. U. S. Pat. Off., a trade mark of Magnaflux Corporation applied to its equipment and materials for magnetic particle inspection.*

MAGNAFLUX CORPORATION

5910 Northwest Highway, Chicago 31, Illinois

New York • Detroit • Dallas • Los Angeles • Cleveland

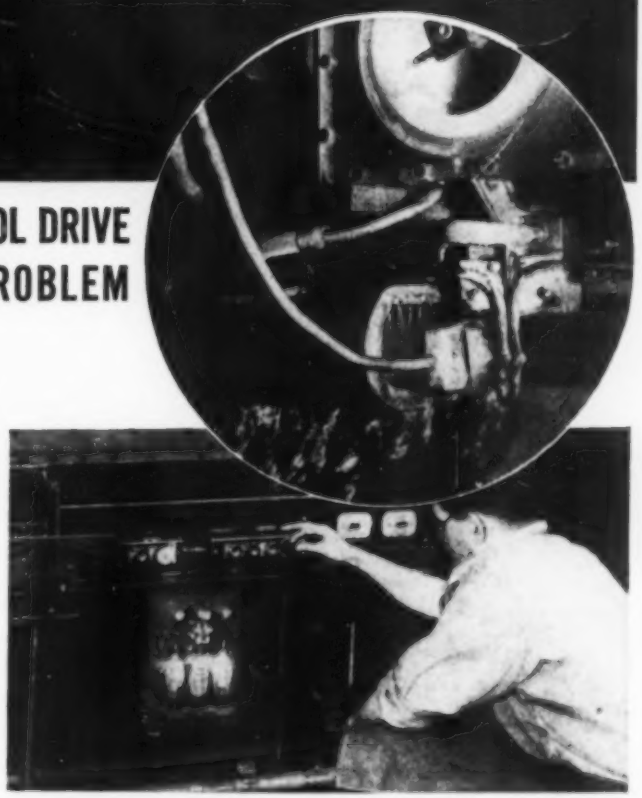


G-E ELECTRONIC HEATER and THY-MO-TROL DRIVE SOLVE DIFFICULT DIE-HARDENING PROBLEM

How could the wearing surfaces of brake dies measuring up to 20 feet in length be efficiently hardened? Because of the distortion difficulties due to the length of the dies, furnace hardening and salt-bath hardening were out of the question.—This was the problem referred to G-E engineers by the Dreis & Krump Manufacturing Company in Chicago.

After carefully analyzing the production requirements of this company, G-E heating specialists scored an electronic double play. The dies to be hardened are passed under the work coil of a G-E electronic heater by a G-E Thy-mo-trol-controlled carriage. Since the Thy-mo-trol drive equipment is connected into the plate circuit of the electronic heater, the speed of the carriage varies directly with the power output of the electronic heater. Thus, with this controlled carriage-speed and power-output ratio, the brake dies are hardened uniformly, with close depth control, and with minimum distortion. Also, Dreis & Krump are now producing a better product at a cost considerably lower than that of any other previous method of die hardening.

Perhaps your heat-treating operations could be similarly improved in speed, quality, and economy with G-E equipment and expert heat engineering. We shall be glad to furnish you with detailed information on G-E electronic heaters and to make specific recommendations for their application to your individual requirements. Just fill out and mail the coupon.



Brake-die wearing surface (above), passing under G-E electronic heater's work coil and into quench shoe for hardening.

Detail of electronic Thy-mo-trol equipment (below), for regulating carriage speed with heater's power output.

Apparatus Dept., Sec. H675-145
General Electric Company, Schenectady 5, N. Y.

My heat-treating problem is .....

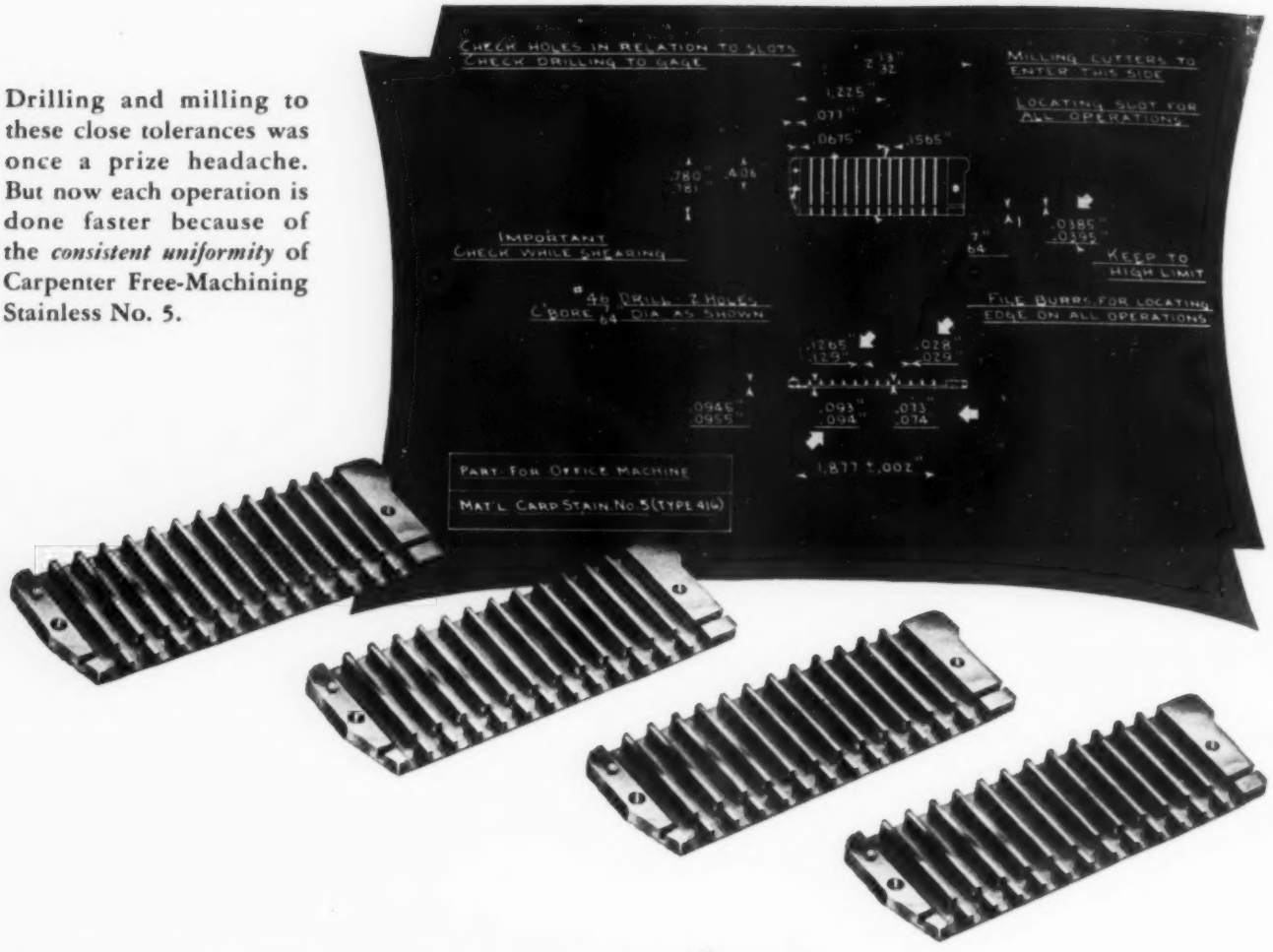
..... Please have a G-E heating specialist get in touch with me.
..... Please send me the following free bulletins:
GEA-4284A "G-E 5-Kw Electronic Heater"
GEA-4637 "G-E 20-Kw Electronic Heater"
GEA-4348 "G-E 50-Kw Electronic Heater"

Name .....
Company .....
Address .....
City ..... State .....

R744

GENERAL ELECTRIC

Drilling and milling to these close tolerances was once a prize headache. But now each operation is done faster because of the *consistent uniformity* of Carpenter Free-Machining Stainless No. 5.


CHECK HOLES IN RELATION TO SLOTS
CHECK DRILLING TO GAGE
MILLING CUTTERS TO ENTER THIS SIDE
LOCATING SLOT FOR ALL OPERATIONS
IMPORTANT
CHECK WHILE SHEARING
KEEP TO HIGH LIMIT
FILE BURRS FOR LOCATING EDGE ON ALL OPERATIONS
PART: FOR OFFICE MACHINE
MAT'L CARP STAIN. NO. 5 (TYPE 416)

You Can Turn It Out *for less*

with Carpenter Free-Machining Stainless

The point on this carburetor needle is made to close tolerances and the needles are produced economically, thanks to the easy machining properties of Carpenter Stainless No. 5. The special cold drawn shape as supplied from the mill also reduced the total amount of machining needed on the job.

On this job the manufacturer got more than the corrosion resistance and strength of Stainless when his orders specified Carpenter Free-Machining Stainless No. 8. Its uniform machinability from lot to lot saved fabricating dollars every day.

• Easier Stainless Fabrication
• Lower Unit Costs

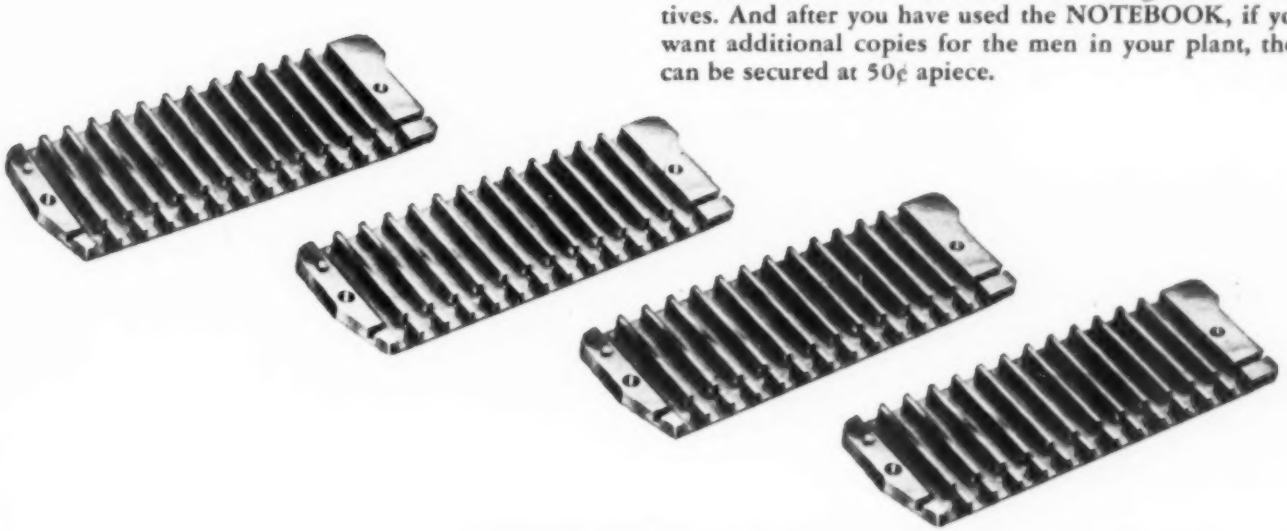
Here is a way to keep your Stainless machining costs in line, even when jobs are intricate and tolerances close.

Helping you to machine parts from Carpenter Stainless at less cost is as much a part of our work as the making of uniform, easy-cutting Stainless Steels. So whenever you run up against a problem of selecting and working with the Stainless that will do your job best, make full use of our experience. Your nearby Carpenter representative can give you personal help in the shop and supply you with printed information to help you shave costs on each Stainless machining operation. For example . . .

Here's Complete Information To Help You Machine Stainless Steel At Less Cost . . .

This NOTEBOOK contains useful information, much of it never before published. It will give you hints to take the kinks out of Stainless machining jobs, reduce rejects and cut costs. In each chapter you'll find a complete Check Chart that lists common "trouble spots", and gives shop tips on how to cure them.

Your nearby Carpenter representative will be glad to give a personal copy of the "NOTEBOOK on Machining Stainless Steels" to Production and Management Executives. And after you have used the NOTEBOOK, if you want additional copies for the men in your plant, they can be secured at 50¢ apiece.



THE CARPENTER STEEL COMPANY, 133 W. Bern St., Reading, Pa.

Carpenter

FREE-MACHINING

STAINLESS STEELS

PROMPT SHIPMENT FROM CONVENIENTLY LOCATED STOCKS

Buffalo	Cleveland	Hartford	Philadelphia
Chicago	Dayton	Indianapolis	Providence
Cincinnati	Detroit	New York	St. Louis

SEE THE CLASSIFIED SECTION OF YOUR TELEPHONE DIRECTORY

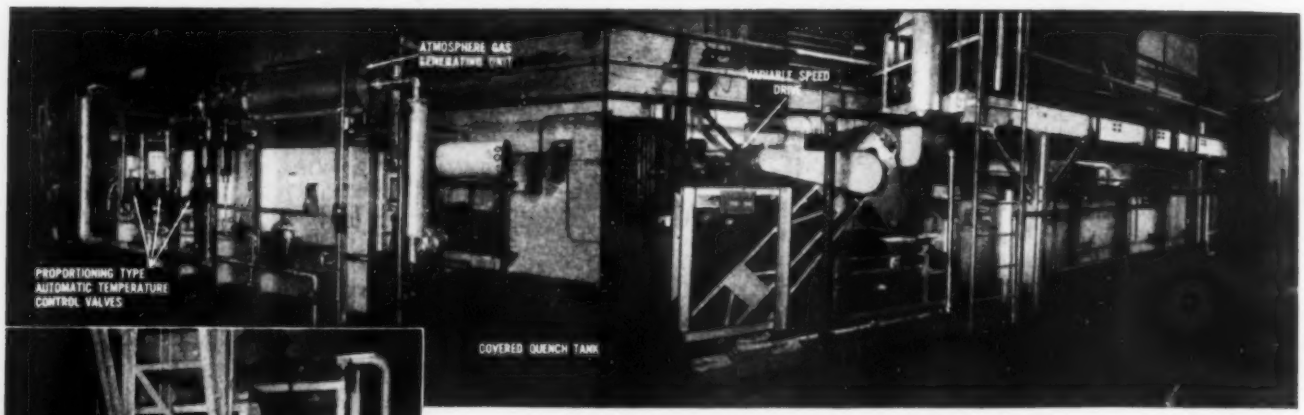
No. 69 of a Series of Typical Installations

Sunbeam STEWART

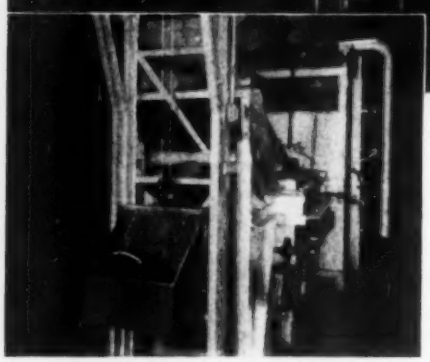
THE BEST INDUSTRIAL FURNACES MADE

For HEAT TREATING HEX-SOCKET SCREWS, PLUGS, PINS and EXTENSIONS

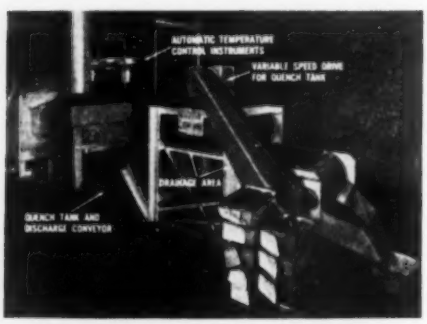
at the Allen Manufacturing Company, Hartford, Conn.


ATMOSPHERE GAS GENERATING UNIT
VARIABLE SPEED DRIVE
PROPORTIONING TYPE AUTOMATIC TEMPERATURE CONTROL VALVES
COVERED QUENCH TANK

New Sunbeam Stewart Fully Automatic and Completely Atmosphere Controlled Continuous Hardening, and Tempering Installation at the Allen Manufacturing Company. This furnace does work that formerly required six rotary furnaces . . . eliminates the expensive degreasing operation between hardening and tempering.



Loading end of the Sunbeam Stewart Atmosphere Controlled Hardening Furnace, showing bucket hopper designed by Allen engineers to save labor and insure uniform loading.



Discharge end of the Sunbeam Stewart Draw Furnace. The work has a clean, scale-free surface and a uniform, deep carbon-black color.

For the important job of securing hard and tough structure together with a uniform deep carbon black color for their famous Hex-Socket screws, the Allen Manufacturing Company chose a Sunbeam Stewart Fully Automatic and Completely Atmosphere Controlled Continuous Hardening, and Tempering Furnace Unit.

This Sunbeam Stewart installation has simplified Allen's heat treating process. It has replaced a gang of rotary furnaces and overcome an expensive degreasing operation between hardening and tempering.

Allen Hex-Socket screws, etc., are conveyed through the Sunbeam Stewart Atmosphere Controlled Hardening Furnace. The load then drops into the conveyorized Quench tank. Next, a conveyor carries the load through the Sunbeam Stewart Atmosphere Controlled Draw Furnace. The load now drops into a second quench tank, and another conveyor carries it to the discharge. These Sunbeam Stewart furnaces are designed to operate on manufactured gas and have a capacity of 800 lbs. per hour. All fuel, air, cooling liquids and the furnace atmosphere are under automatic control.

This installation is typical of the industrial furnaces Sunbeam Stewart engineers are building every day to meet the specified requirements of manufacturers all over the continent. In addition, Sunbeam Stewart builds a full line of standard furnaces.

SUNBEAM STEWART INDUSTRIAL FURNACE DIVISION of SUNBEAM CORPORATION

(*Formerly* CHICAGO FLEXIBLE SHAFT CO.)

Main Office: 4433 Ogden Ave., Dept. 108, Chicago 23, Ill.—Canada Factory: 321 Weston Rd., So., Toronto 9

A letter, wire or 'phone call will promptly bring you information and details on SUNBEAM STEWART furnaces, either units for which plans are now ready or units especially designed to meet your needs. Or, if you prefer, a SUNBEAM STEWART engineer will be glad to call and discuss your heat treating problems with you.

HOW TO LICK A PROBLEM IN A FEW STEPS

Let's say some change in your product design, production schedule or fabricating methods gives you a steel problem. It may involve metallurgy, delivery, finish, gauge or width—any of a score of "variables" in specifications.

At Weirton, the solution is only "a few steps" away. For the Weirton Steel Company is an integrated mill, with all phases of operation centralized and coordinated under one roof. Metallurgist, production man, salesman and shipping supervisor can get together on short notice to give your problem prompt attention.

Weirton customers recognize this benefit as the "plus factor" in Weirton steels—Weirite, Weirzin, Weircoloy, Weiralead, hot and cold rolled strip, sheets and ternes, cold rolled spring steel, N-A-X High-Tensile.

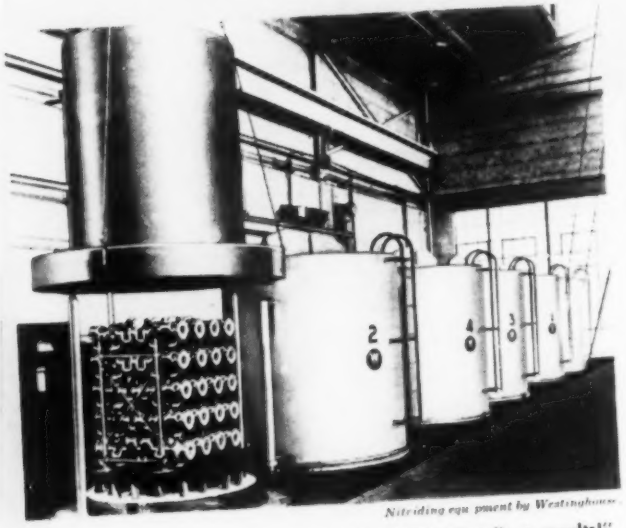
WEIRTON STEEL CO.

WEIRTON, W. VA. *Sales Offices in Principal Cities*

Division of **NATIONAL STEEL CORPORATION** *Executive Offices, Pittsburgh, Pa.*

3 REASONS

Why WESTINGHOUSE Uses INCONEL for NITRIDING Furnaces



Nitriding equipment by Westinghouse

At PACKARD MOTOR CAR COMPANY, "Excellent results!" were reported from Inconel hoods and racks used in the nitriding of crankshafts. Hoods were gas-tight welded from Inconel sheet; racks, from Inconel bar and tubing.

Nitriding equipment by Westinghouse

At WRIGHT AERONAUTICAL CORPORATION, Inconel hoods and racks set service records. Inconel is especially recommended where equipment must maintain strength and resist oxidation at high temperatures.

WESTINGHOUSE found that many alloys wouldn't do for a nitriding furnace's metal hood and rack. When ammonia is dissociated (900° to 1100° F.), nitrogen is released—and many alloys quickly absorb it. They become embrittled, causing metal failures.

Then production stops...repairs and replacements are costly.

Westinghouse decided to use Inconel*. Why? Because Inconel, in high temperature nitriding atmospheres, couldn't be matched!

- **Inconel absorbs nitrogen superficially only and not harmfully. Thus it provides lasting nitriding service.**
- **Inconel's 80 nickel—14 chromium content resists oxidation, lends strength, ductility and thermal endurance.**
- **Inconel can be easily formed and welded into gas-proof hoods and durable racks.**

You can readily understand why Westinghouse standardized on Inconel. Nitriding furnaces installed before the war—with Inconel hoods and racks—are still in service today.

INCONEL CAN HELP YOU

If high temperatures are a problem, investigate Inconel. Chances are good that Inconel will out-perform the metals you are now using in your plant.

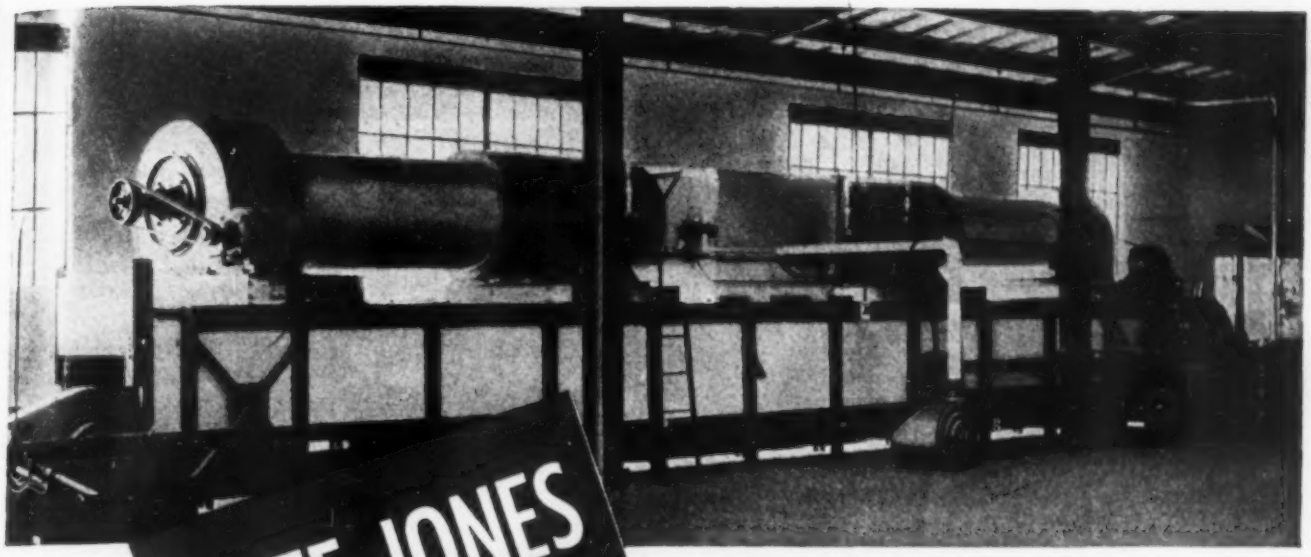
Write for your copy of
"FOR LONG LIFE AT HIGH TEMPERATURES"
*Reg. U.S. Pat. Off.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

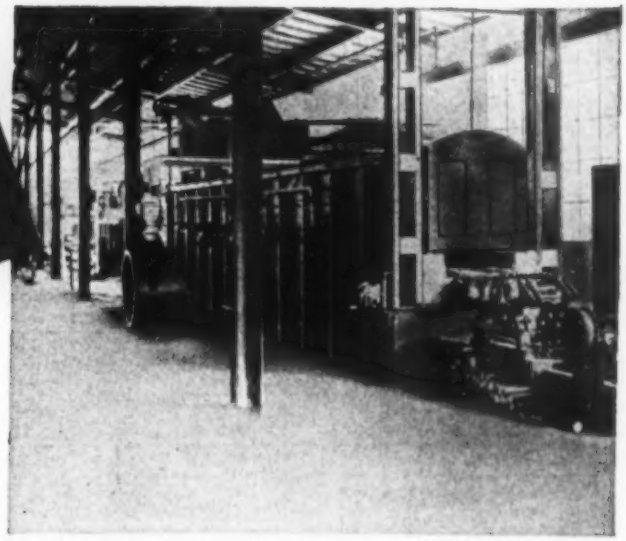
INCONEL
(80 NICKEL-14 CHROMIUM)

—for long life at high temperatures

INCO TRADE MARK



TATE-JONES & CO., INC.
Since 1919



Established in 1898, Tate-Jones and the advancements in methods of heat treating with gas and oil have been parallel. To meet the rigorous demands requiring exact applications of heat with maximum efficiency in fuel and time, Tate-Jones has used Spencer Turbos since 1919.

Heat treating engineers of experience recommend Spencer Turbos primarily because of three accepted facts:

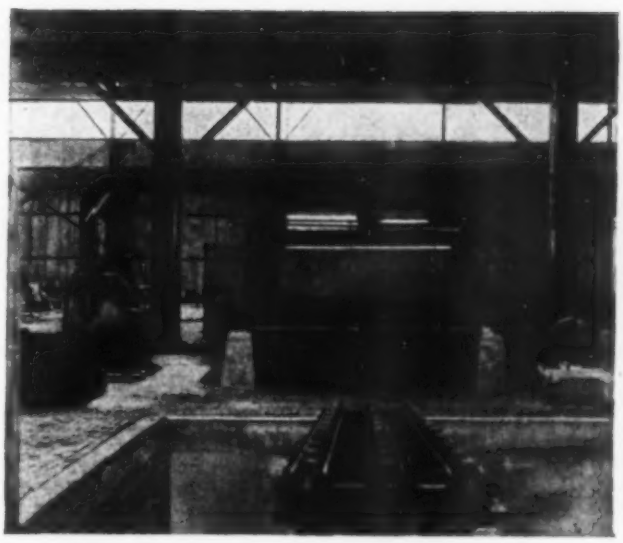
It is the simplest and sturdiest type of blower available for gas and oil-fired service.

It provides constant pressures automatically, without surges, without vibration or noise.

It maintains high efficiencies at all loads and therefore a high overall-operating efficiency.

Standard sizes from 35 to 20,000 c.ft.; 1/3 to 300 H.P.; 8 oz. to 5 lbs. Single or multi-stage, two or four gearing. Special gas-right and non-corrosive construction available.

Ask for the Turbo Data Book and Bulletins.



THE SPENCER TURBINE COMPANY
HARTFORD 6, CONN.

SPENCER HARTFORD TURBO-COMPRESSORS

2S0W

It takes all seven..

to permit you to select the Insulating Fire Brick with the correct *balance* of thermal and physical properties for each service in your plant.

PROPERTIES	INSULATING BRICK			INSULATING FIRE BRICK AND FIREBLOK			
	Sil-O-Cel Natural	Sil-O-Cel C-22	Sil-O-Cel Super	JM-1620	JM-20	JM-23	JM-26
Density—lb. per cu. ft.	30	38	40	29	35	42	48
Transverse Strength—lb. per sq. in.	140	115	90	60	80	120	125
Cold Crushing Strength—lb. per sq. in.	400	700	300	70	115	170	190
Linear Shrinkage—Percent	1.4 @ 1600F	0.8 @ 2000F	2.0 @ 2500F	0.0 @ 2000F	0.0 @ 2000F	0.3 @ 2300F	1.0 @ 2600F
Reversible Thermal Expansion—Percent	0.1 @ 1600F	0.7 @ 2000F	1.3 @ 2000F	0.5—0.6 @ 2000F	0.5—0.6 @ 2000F	0.5—0.6 @ 2000F	0.5—0.6 @ 2000F
Conductivity at Mean Temperature	∥ ⊥						
500F	1.01 .67	1.67	1.70	.77	.97	1.51	1.92
1000F	1.13 .79	1.88	1.95	1.02	1.22	1.91	2.22
1500F	1.24 .90	2.08	2.19	1.27	1.47	2.31	2.52
2000F	— —	—	2.45	—	1.72	2.70	2.82
Recommended Service							
Back Up	1600F	2000F	2500F	2000F	2000F	2300F	2600F
Exposed	—	—	—	1600F	2000F	2300F	2600F
Recommended Mortar for Setting Brick	Sil-O-Cel Mortar	Sil-O-Cel Mortar	Sil-O-Cel Super Brick Mortar	J-M No. 1626 Cement	J-M No. 1626 Cement	J-M No. 1626 Cement	J-M No. 1626 Cement

Note: 1. Above tests are in accordance with ASTM tentative standards.
2. Conductivity is expressed in Btu in. per hr per sq ft per deg F at the designated mean temperatures.
3. ∥ —with heat flow parallel to brick strata.
⊥ —with heat flow perpendicular to brick strata.

No one brick can perform properly under all steel mill service conditions. That's why Johns-Manville makes seven types of Insulating Brick and Insulating Fire Brick. Each is designed for a specific job . . . and *engineered* to do its job with maximum efficiency.

The three J-M Insulating Brick provide great structural strength; the four J-M Insulating Fire Brick combine strength with exceptional resistance to spalling. All offer the advantages of light weight and low conductivity. They are recommended as back-up insulation or insulating fire brick for all industrial requirements.

For complete details, write Johns-Manville, Box 290, New York 16, N.Y.

JOHNS-MANVILLE *First in* **INSULATIONS**

They're NEW...

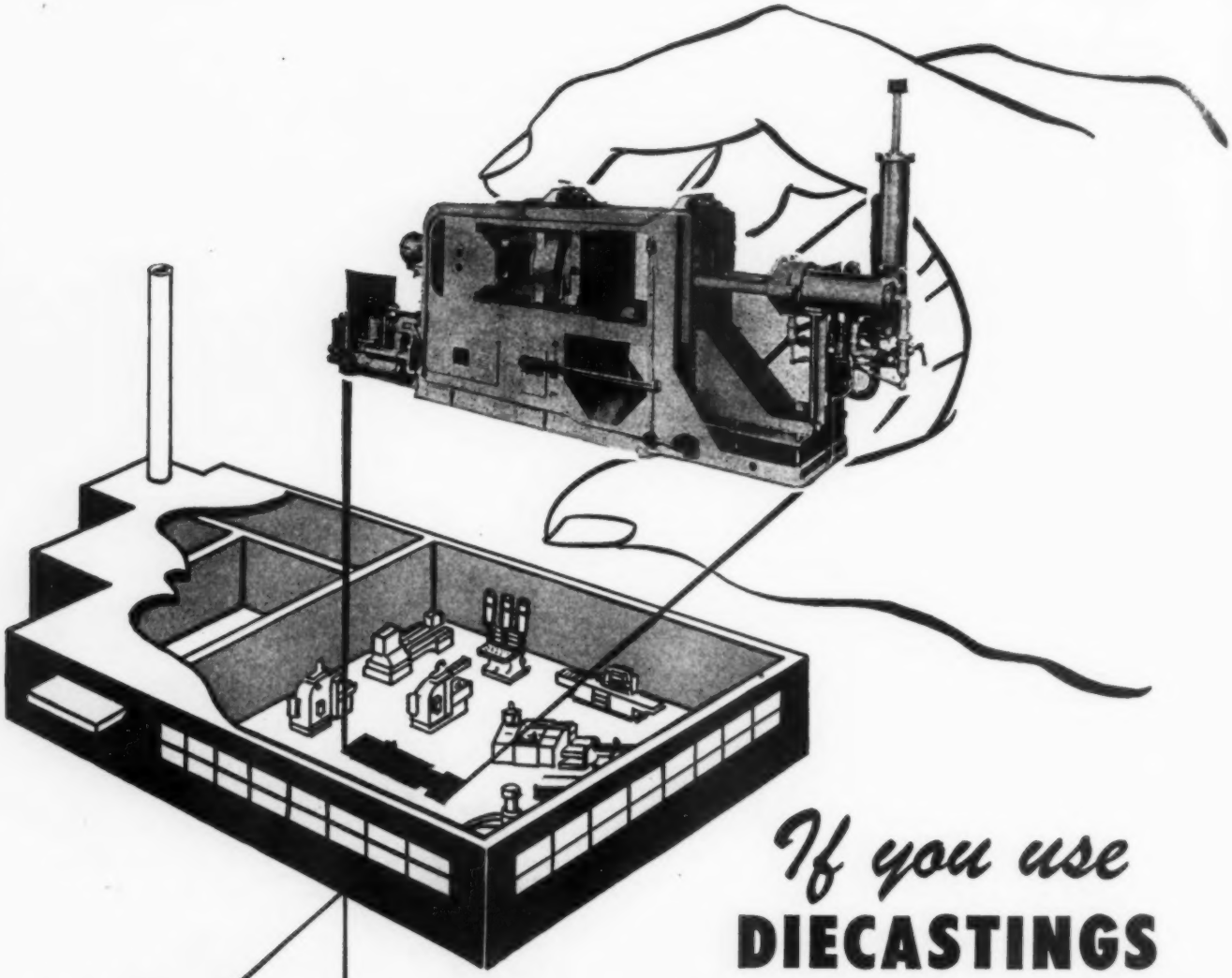
4 "HOW-TO-DO-IT" [illegible] BY ALCOA

Bring your workers up to date on these four methods of joining Alcoa Aluminum. These new films are available for both 16 mm. and 35 mm. sound motion picture projectors. May be borrowed or purchased.

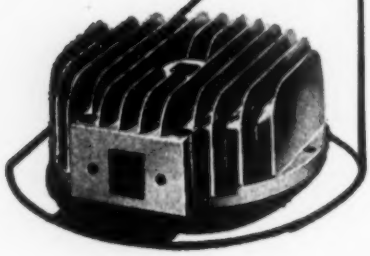
Call the nearby Alcoa office. Or write ALUMINUM COMPANY OF AMERICA, 2101 Gulf Building, Pittsburgh 19, Penna.

ALCOA ALUMINUM

IN EVERY COMMERCIAL FORM



If you use
DIECASTINGS
THERE'S A *Spot* IN YOUR PLANT FOR A *Lester-Phoenix* MACHINE



- Every manufacturer and diecaster who knows LESTER equipment will find a spot for the *new* LESTER-PHOENIX machine.
- They know that LESTER-PHOENIX diecastings are smooth, dense, low in porosity . . . that LESTER-PHOENIX sets new production records and lowers production cost.
- Partial list of "firsts" on the new LESTER-PHOENIX diecasting machines: One-piece, cast alloy steel frame . . . Largest and strongest die-height adjusting screw . . . Faster die opening and closing . . . Four metal-to-metal columns keep die closed . . . Independent control of both injection speed and injection pressure . . . Highest final pressure until casting chills . . . Positively supported platens eliminate flash—and make better castings for you.

• *Write Today,*
telling what metal you cast and we will send complete LESTER-PHOENIX data.

LESTER-PHOENIX, INC.
2619 Church Avenue • Cleveland 13, Ohio

LESTER-PHOENIX
DIE CASTING MACHINES

Used for spinning yarn in a modern rayon plant, these stainless steel cylinders represent but one of many applications for long-lasting ENDURO. Others include dyeing and bleaching equipment, agitators, dry cans, fulling machines, reels and sizing equipment.

Enduro Pays

in many ways

Universal accepance is an old story with Republic ENDURO Stainless Steel in all branches of the textile industry.

Right from the start, textile men welcomed the remarkable ease of cleaning which characterized dyeing equipment made of smooth, lustrous ENDURO. They were quick to recognize the inherent advantages of a material which assured "true" colors . . . eliminated danger of contamination in switching from dark to light colors.

Now, after many years of service in large and small plants, countless installation records conclusively prove the complete dependability, economical maintenance and long, trouble-free life of equipment made of Republic ENDURO Stainless Steel.

For complete information, write to:

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York, 17, N. Y.

Republic
ENDURO STAINLESS STEEL
Reg. U. S. Pat. Off.

Other Republic Products Include Carbon and Alloy

Lockheed P-80 Shooting Star.
Photo courtesy of Lockheed Aircraft Corporation

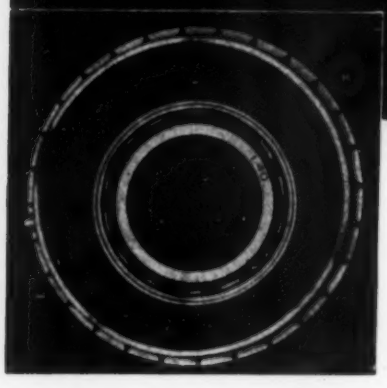
jet propulsion

demands the best . . .

that's why

ACCOLOY Stainless Steel Castings

are specified



Since the inception of the JET ENGINE Program, Alloy Casting Company has had the privilege of working with several of the JET ENGINE manufacturers in the development of High Temperature materials to withstand the rigid requirements of cyclic heating and cooling. Much of this development work still remains secretive.

The photograph at left illustrates a special STAINLESS STEEL casting spun at 2 MILES PER MINUTE in a metal die. Parts machined from this tube had to withstand the most rigid specifications ever set up for a casting. The shroud rings are CENTRIFUGALLY cast to tolerances heretofore unheard of in the casting industry.

JET PROPULSION castings are just one of the many phases of our development work. Consult us on your HEAT and CORROSION problems.

Next time call an **ACCOLOY** *engineer.*

ALLOY CASTING COMPANY
CHAMPAIGN, ILLINOIS ENGINEERING OFFICES IN PRINCIPAL CITIES

How to Hold a Jiggling 2-Ton Baby

SUPPORTING a 2-ton roller, vibrating 500 times per minute is no job for weak-muscled metals. In the breast roller section (above) of the Fourdrinier (paper making) machine *Beryllium Copper* "shake springs" must hold an oscillating two-ton roller and do it without buckling, corroding, crystallizing or requiring frequent nursing by the maintenance squad.

Pusey and Jones Corporation, one of the top manufacturers of paper machines, picked Riverside *Beryllium Copper* for shake springs after testing many other materials.

Riverside *Beryllium Copper* has unusually high strength and excellent hardness, extraordinary resistance to wear, fatigue and corrosion.

Get more information about the many advantages of Riverside *Beryllium Copper*, also get data on Riverside's two other alloys, *Nickel Silver* and *Phosphor Bronze* by writing for catalogs of all three.

INSIDE RIVERSIDE

The excellent distribution facilities in the Riverside area, help us to give our customers giant-stride delivery service.

THE
RIVERSIDE METAL COMPANY
NEW YORK CHICAGO RIVERSIDE • NEW JERSEY HARTFORD CLEVELAND

This Present Age . . 5

In the forefront of our plans for the future we place the training and education of every youth who enters our organisation. Schemes are in operation and there is already an equal opportunity for all who desire to avail themselves of the facilities provided. Science, technology and commercial knowledge are the three great requirements of industry. It will be our privilege to ensure that these aims are rightly and efficiently fostered within the framework of the national educational policy. By the pooling of knowledge for the common good, industry is fulfilling one aspect of its rightful service to the nation. For a boy of intelligence and imagination, apprenticeship to the iron and steel industries provides training for a life's work requiring initiative, technical knowledge of a high order and the ability to understand one's fellow men. The successful organisation of many thousands of workers presents problems of understanding in human affairs equal to the technical problems of economic production. Industry is a major part of our social life as well as the means of national wealth, therefore the discipline of education provides the means for developing those talents with which each one is endowed, and ultimately enriching the inheritance of the country whose citizens we are.

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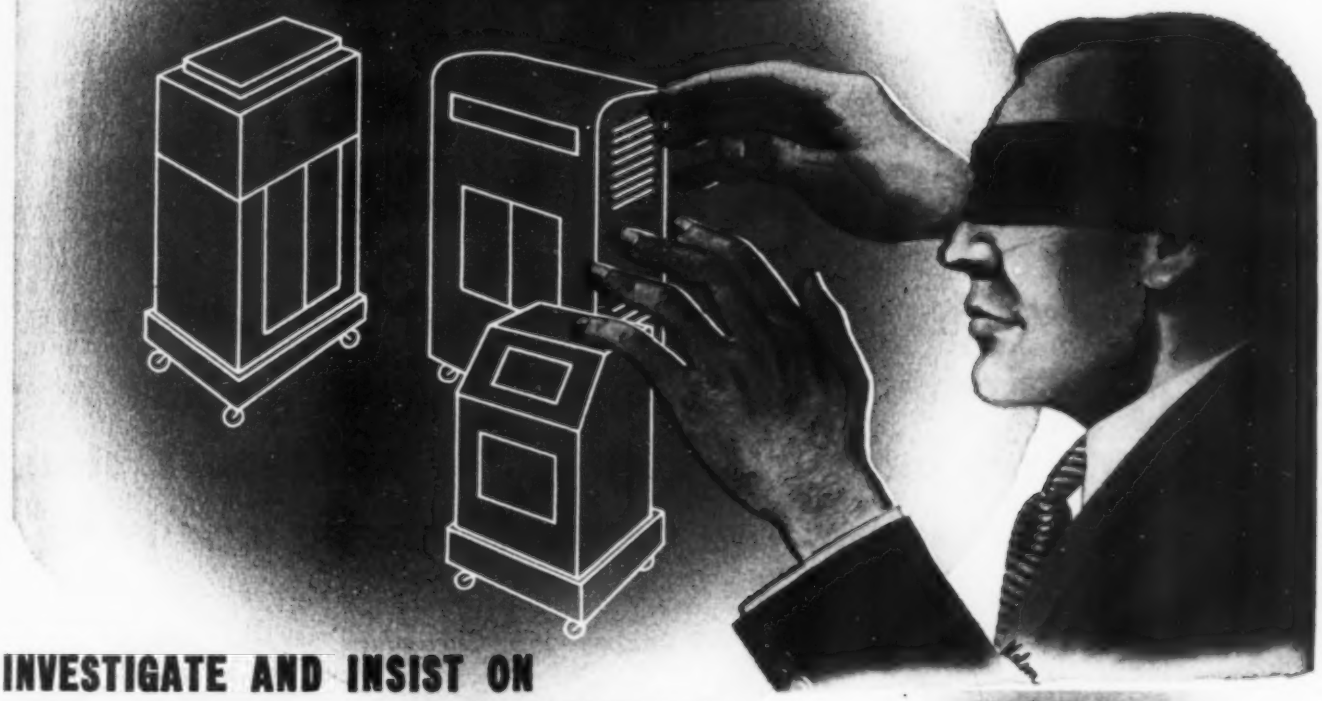
Don't buy an electronic heater *blindly*



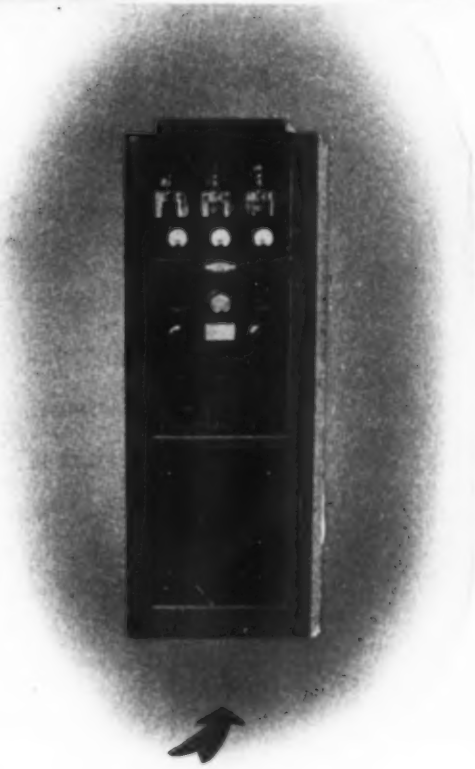
INVESTIGATE AND INSIST ON PROOF BY TRIAL — WITH AUTOMATIC OR HAND-OPERATED APPARATUS

Have you soldering, brazing, surface-hardening, annealing or other heat-treating operations? Or do you use heat to treat non-metallic substances such as plastics, plywood, rubber, etc.?

It is quite possible that you can use electronic heating apparatus for these operations, profitably replacing older and slower heating methods. The savings and increased efficiency are decidedly worthwhile. The speed-up in production is as great as 700% in some instances. Work that formerly took minutes or hours now requires only SECONDS.

Investigate the possibilities of high frequency heating for your production. But be sure to get plenty of sound experienced advice before you buy. Don't just buy a "machine." Let our engineers prove to you by actual demonstration under your own conditions, how Scientific Electric equipment fits your exact needs. Remember, there is no such thing as an all-purpose electronic heater. Each individual operation and each factory production set-up requires a specific type of installation, with the proper combination of frequency and power output. Consult us without obligation. We will engineer the right installation to your particular requirement. Buy nothing till we've PROVED IT BY TRIAL for you.

NOW — IMMEDIATE DELIVERY



Scientific Electric Electronic Heaters are made in the following range of power: 1—3—5—7½—10—12½—15—18—25—40—60—80—100—250 KW. — and range of frequency up to 300 Megacycles depending on power required.

Scientific Electric

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HEAT AND CORROSION RESISTING ALLOYS IN ROLLED MILL FORMS

When you need rolled heat and corrosion resisting alloys check our inventory list first. We have 800,000 lbs. of warehouse stocks ready for you in the following analyses:—

MISCO METAL	*35 Nickel - 15 Chromium - Type 330*
MISCO K	*25 Chromium - 20 Nickel - Type 310*
MISCO B	*25 Chromium - 12 Nickel - Type 309*
MISCROME 3	*27 Chromium - Type 446*

Over 200 sizes are on hand for immediate shipment upon receipt of your order

SHEETS	4 sizes in 6 gauges	HEXAGONS	5 sizes
PLATES	3 sizes in 4 gauges	FLATS	19 sizes
ROUNDS	23 diameters	PIPE	9 standard iron pipe sizes
SQUARES	9 sizes	NUTS	5 U.S. standard sizes
WELDING ROD	5 sizes in 8 alloys—Gas and Arc		

For ready reference send for our monthly inventory list and Warehouse Price Book

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Michigan Steel Casting Company

MISCO
Heat and Corrosion Resistant Alloys

One of the World's Pioneer Producers of Heat and Corrosion Resisting Alloys

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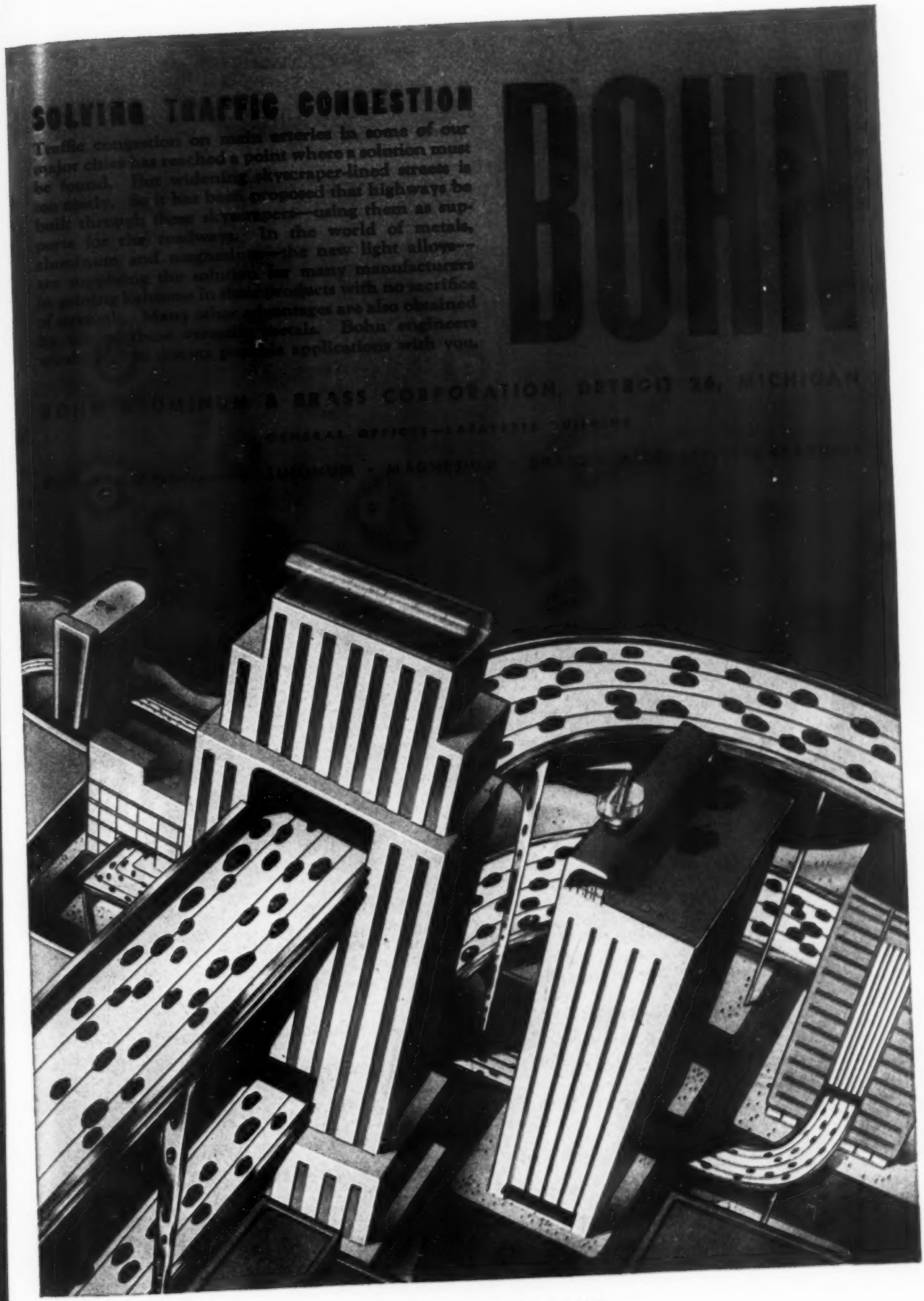
SOLVING TRAFFIC CONGESTION
Traffic congestion on main arteries in some of our major cities has reached a point where a solution must be found. But widening skyscraper-lined streets is too costly, so it has been proposed that highways be built through those skyscrapers—using them as supports for the roadways. In the world of metals, aluminum and magnesium—the new light alloys—are supplying the solution for many manufacturers in getting lightness in steel products with no sacrifice of strength. Many other advantages are also obtained in these remarkable metals. Bohn engineers would like to discuss possible applications with you.
BOHN
ALUMINUM & BRASS CORPORATION, DETROIT 26, MICHIGAN

Jalloy is a special alloy steel, made by Jones & Laughlin for machine and equipment parts that must stand up under the most severe operating conditions. It is ideal for shafting that is subjected to repeated shocks, torsion and dynamic stress. Jalloy is readily forged and heat treated. Write today for information.

JONES & LAUGHLIN STEEL CORPORATION

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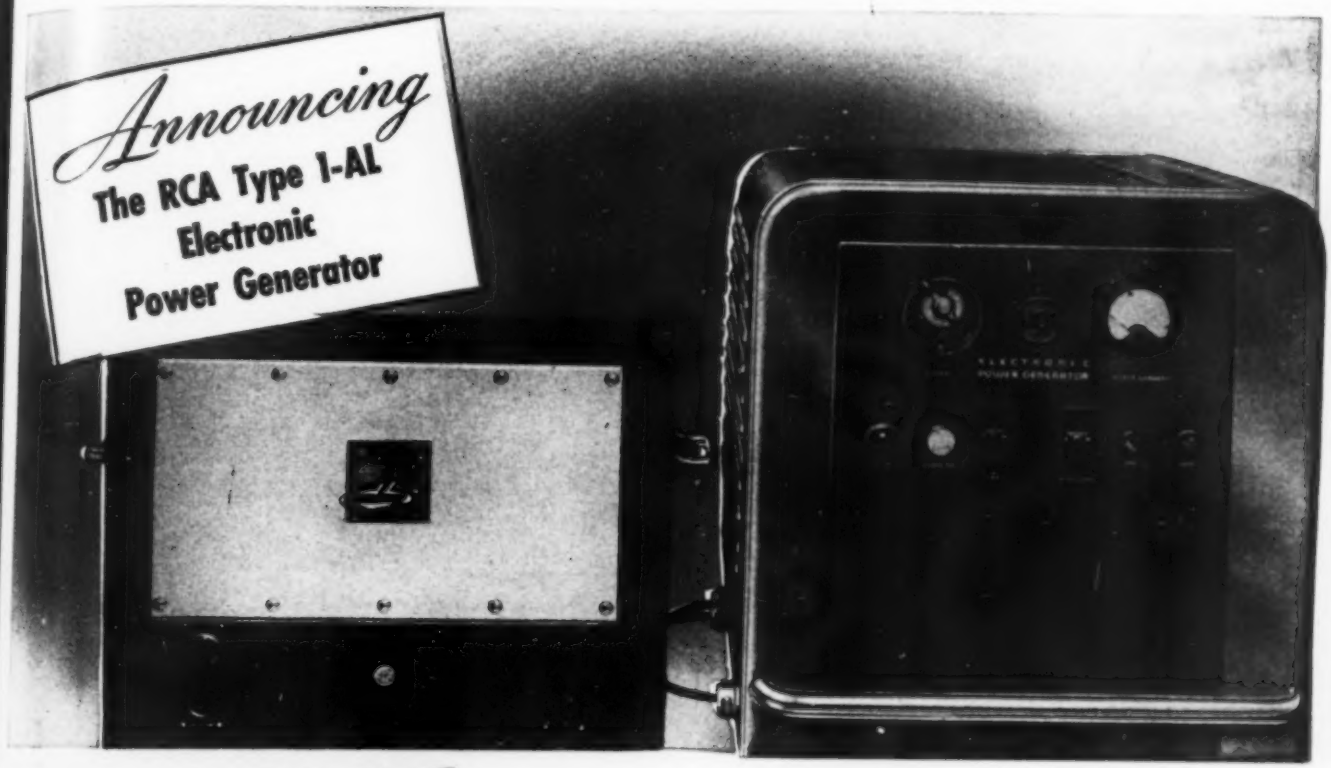


SLASHES soldering and brazing time

Here's a compact, 1-kw unit that brings all the advantages of electronic heating to small soldering and brazing jobs. It puts repetitive, manual operations on a "push-button" basis; serves for continuous or conveyor applications.

BOOSTS OUTPUT, CUTS COSTS, IMPROVES QUALITY

Look at the record: Using high-frequency heating, condenser-can soldering was increased from 100 to 2500 units per hour. A complicated, expensive assembly operation on loudspeakers became a simple, ten-second job. A manufacturer of small motor rotors boosted output 400 per cent. In these and many other cases, electronic heat helped do the job faster, cleaner, better, at less cost.

CONVENIENT, EASY TO OPERATE, PRECISION CONTROL

The Model 1-AL is divided into two units to save working space. Only the applicator (*above, left*) is needed in the work area; the generator can be located up to 25 feet away. Suitable work coils are connected to the applicator and fitted to the part to be soldered or brazed. A single switch starts the generator. Output can be varied by a single control at the applicator. No manual tuning is required. A "universal" output transformer provides a match for any load and keeps the work coil at a safe, low voltage. A foot-switch starts the heat cycle; a work-interval timer provides *automatic* shutoff. Thus the operator has free use of hands during this period. "ON-OFF" push buttons are provided on both the applicator and generator for convenience and manual control when desired.

Accurate output control and precision tuning assure unvarying heat cycles. Power can be concentrated and focused on exactly the area desired—and to just the right depth. When soldering, the base metal is heated directly and the metal in turn melts the solder. "Cold" soldered joints cannot occur; uniformity is assured.

RCA

ELECTRONIC HEATING

RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

In Canada: RCA VICTOR Company Limited, Montreal

FOR QUICK FACTS USE THE COUPON

Radio Corporation of America
Dept. 53-L, Electronic Apparatus Section
Camden, New Jersey

Please send us complete information on the new RCA 1-AL electronic power generator for fast, low-cost soldering and brazing. We have the following application in mind.

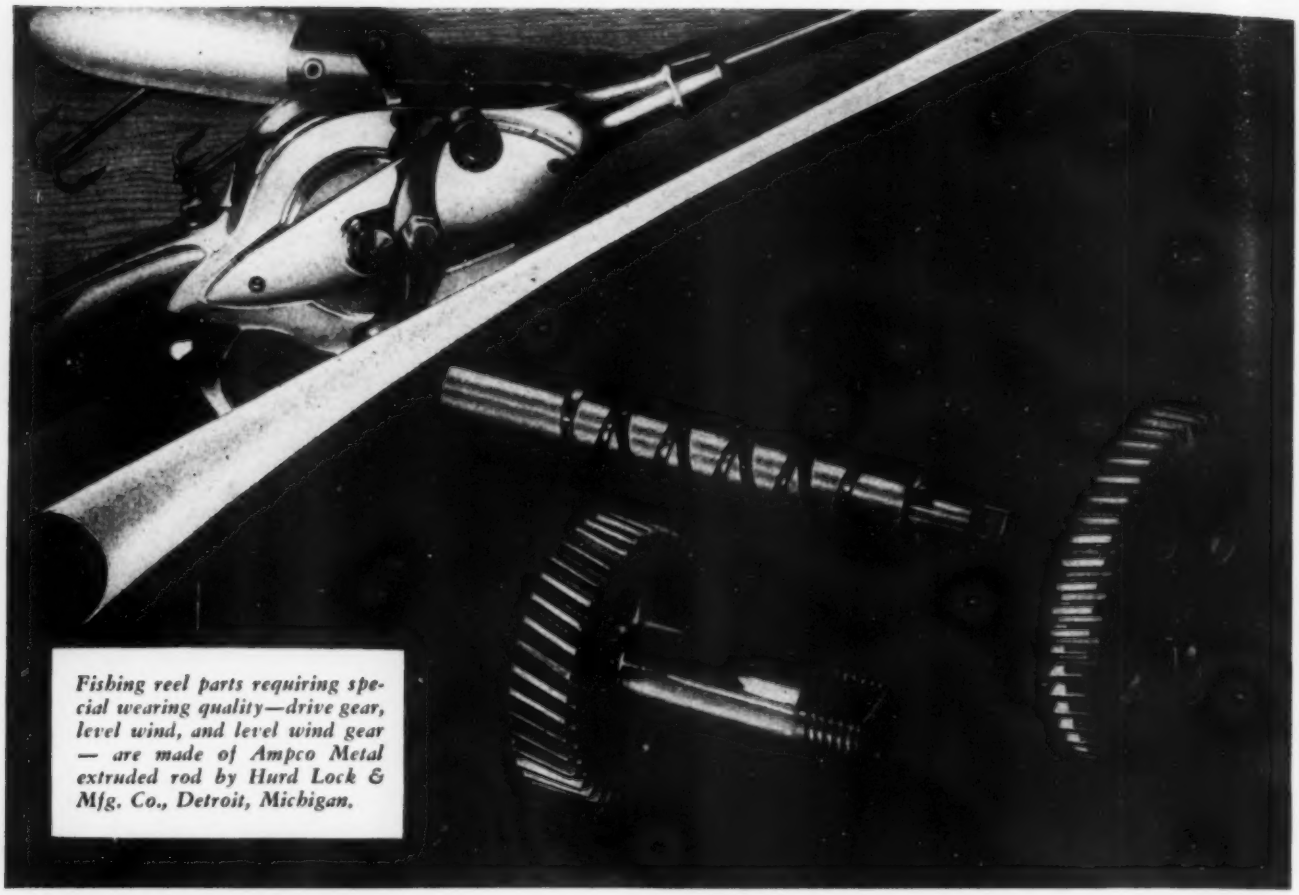
Application_____

Name_____ Title_____

Company_____

Street_____

City_____ Zone____ State_____



Fishing reel parts requiring special wearing quality—drive gear, level wind, and level wind gear — are made of Ampco Metal extruded rod by Hurd Lock & Mfg. Co., Detroit, Michigan.

To cut production costs and improve part-performance

use Ampco Metal extruded rod

Double advantage of Ampco Metal extruded rod . . .

1 Production savings of extruded stock

- ✓ Sizes parallel requirements—reduces waste.
- ✓ Reduces machining time and costs.
- ✓ Compact structure cuts rejections.

2 Performance advantages of Ampco Metal

- ✓ Higher fatigue and impact strength.
- ✓ Higher compressive strength.
- ✓ Resistance to corrosion.
- ✓ Light weight.

When you specify metal for critical parts, it pays to consider the double advantage of using Ampco Metal extruded rods — increased production savings for you, and improved part-performance for your customers.

Ampco Metal is an aluminum-bronze type alloy with superior wearing qualities ideal for parts subject to impact and fatigue, compression, and corrosion.

Ampco's extrusion press is one of the largest in the middlewest and one of the few in the world devoted to the extrusion of aluminum bronze. Extruded Ampco rods are produced and stocked in two grades of Ampco Metal and two grades of Ampcoloy bronze — ask your nearby Ampco engineer to help you specify the proper grade for your requirements.

Write for Bulletin 64A.

REG. U. S. PAT. OFF.

AMPCO Metal
The Metal without an Equal

AMPCO METAL, INC.
Department MP-12 • Milwaukee 4, Wis.
Field Offices in Principal Cities

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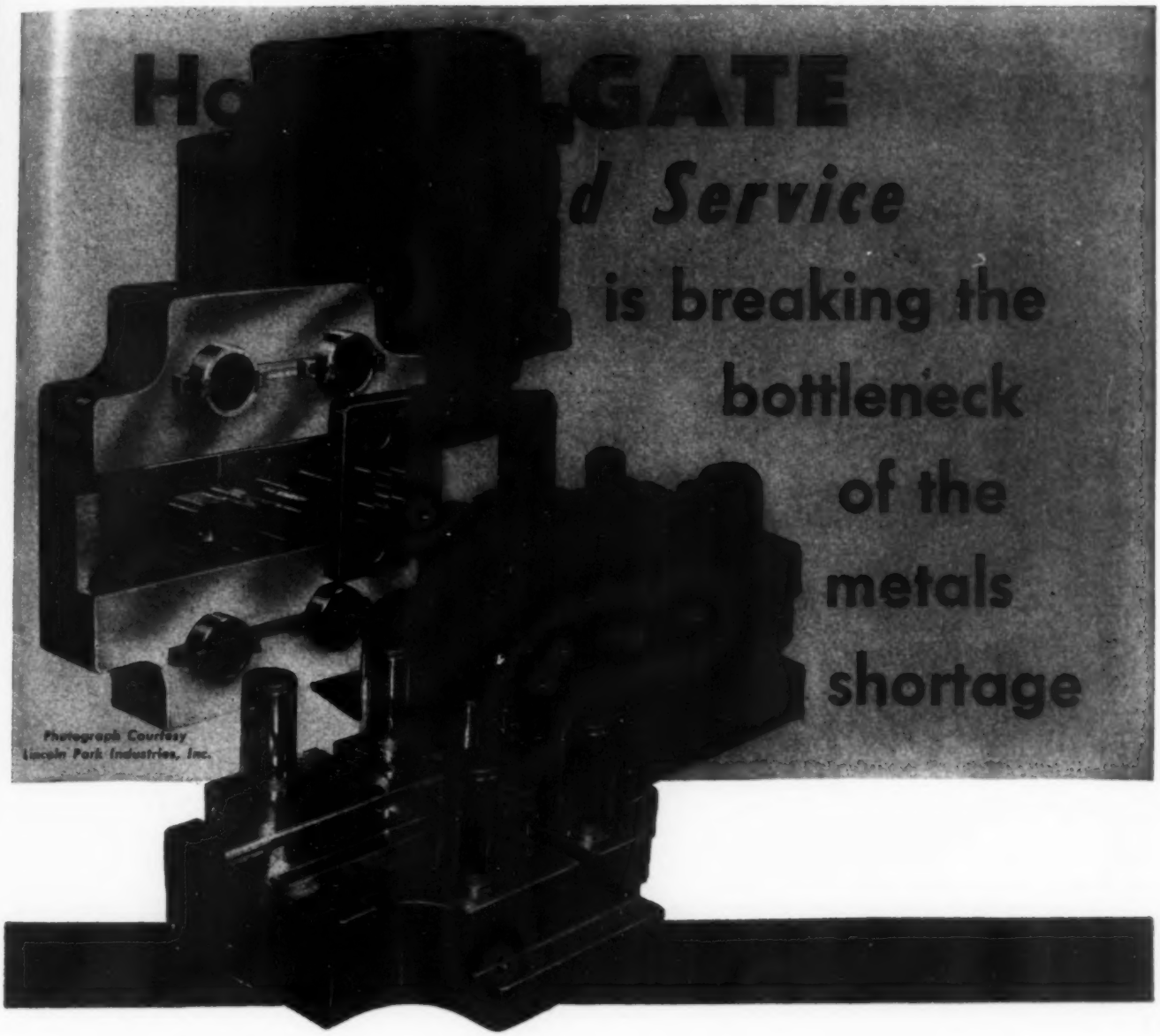


MANY MANUFACTURERS have asked us whether it is possible to make an assembly or part in another metal *temporarily,* and still use the fabricating and stamping tools, when the time comes, for the preferred metal.

It's not only frequently *possible*... Colgate is *doing it.* By designing double purpose dies so that they may be used, during this interim period with a second-choice material, and later converted, Colgate is breaking the bottleneck of the metals shortage.

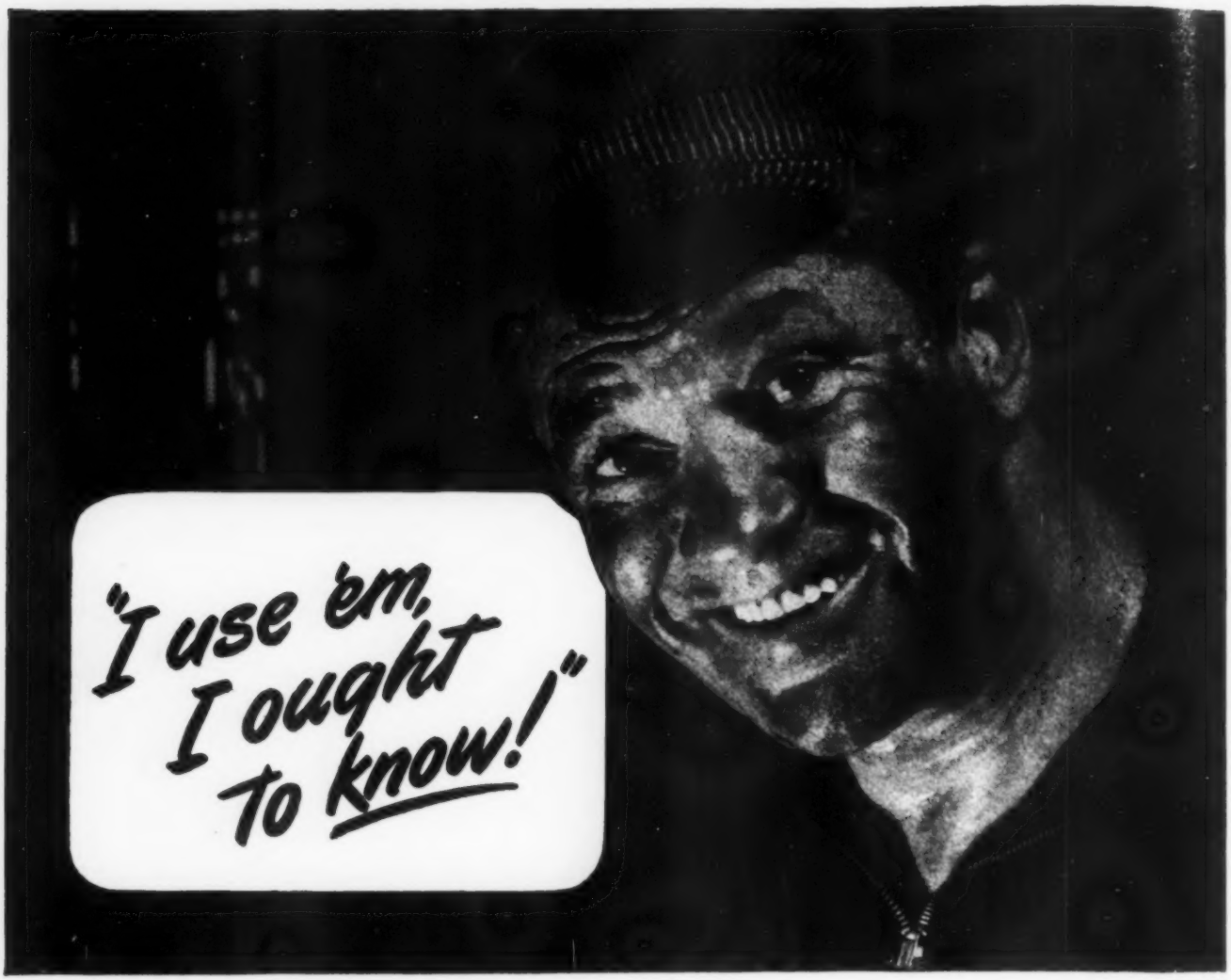
Dies engineered to serve a double purpose is just one example of Colgate *Engineered Service* in sheet metal fabricating and stamping of aluminum, magnesium, stainless steel and many other light metals.

If your product is ordinarily made of steel (let's say), perhaps some other material could be used. Then, when steel becomes *available,* in many cases the tools can be converted, at reasonable cost, through Colgate's *Engineered Service.* Write for more information.

STAMPING • FORMING • DRAWING • WELDING • FINISHING • ASSEMBLING

COLGATE

THERE'S A *Federated* SOLDER FOR EVERY JOB—



FEDERATED SOLDERS are tops in quality, uniformity and dependability. They have maximum strength and fluidity. They possess excellent bonding qualities, fine grain structure and uniform melting points.

All of these properties add up to quicker, easier application . . . more production in less time. That's economy—and satisfaction. Try Federated Solder.

Federated Solders are available in the following types:

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MADE IN ALL STANDARD COMPOSITIONS
SPECIAL ALLOYS TO SPECIFICATION

FMD Federated

FEDERATED METALS DIVISION
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Nation-wide service with offices in principal cities

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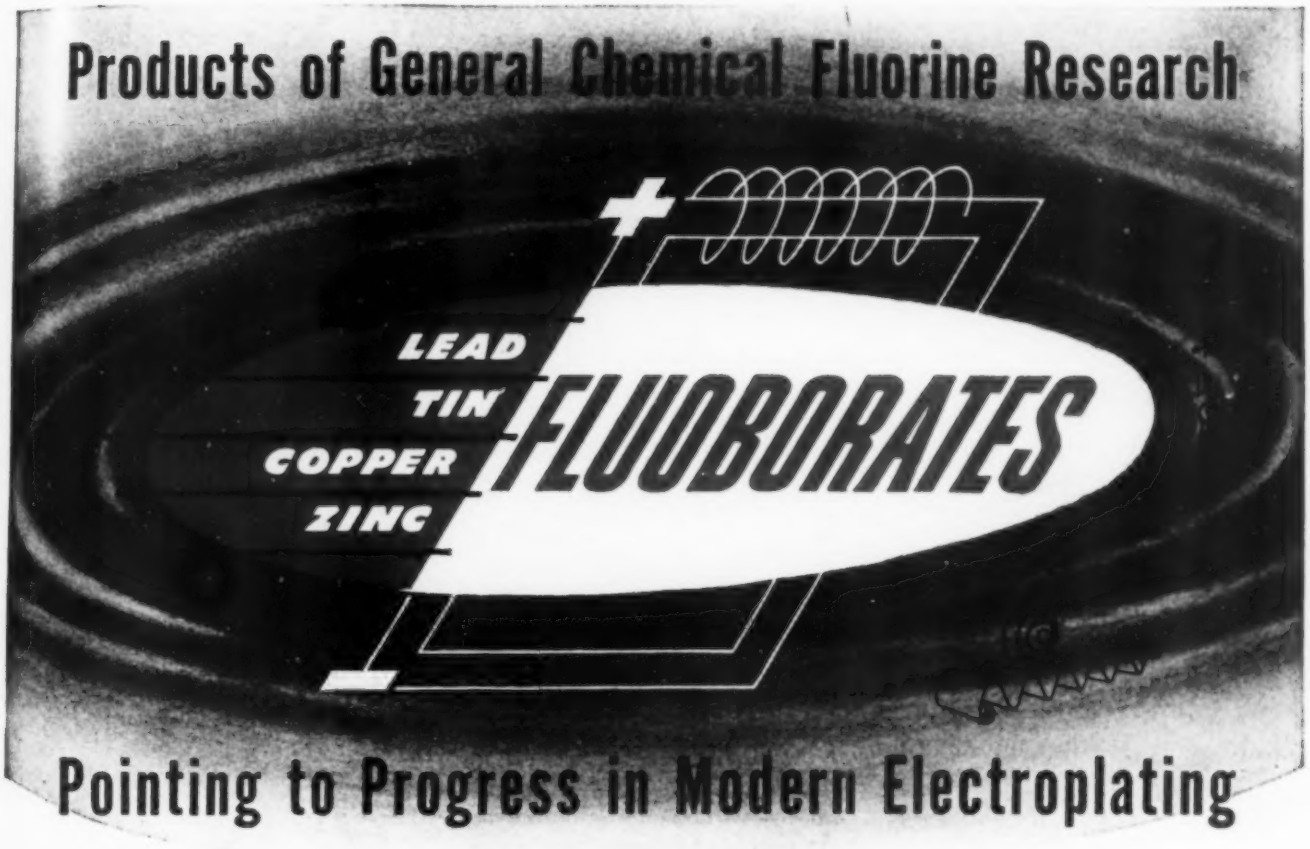
Products of General Chemical Fluorine Research



Pointing to Progress in Modern Electroplating

Progress and important advancements in modern electroplating lie ahead with the broadening use of General Chemical Metal Fluoborate Solutions. Today—fluoborate baths are proving outstanding for many lead, tin, lead-tin alloy, copper, zinc and other applications. Tomorrow—Metal Fluoborates hold still greater promise since their superiority to ordinary baths is indicated both by the unusual characteristics of the fluoborate electrolyte and by the type of deposits obtained.

To the electroplater, the Metal Fluoborates, generally, offer such advantages as: 1. Concentrated solution form; no mixing or dissolving necessary. 2. Simplicity of bath preparation and ease of control. 3. Stability of composition, high conductivity, and good covering power. 4. Fine-grained deposits of good color. 5. High-speed operation, with practically 100% anode and cathode efficiency.

These advantages can mean real economy, efficiency, and convenience in your plant. So investigate the Metal Fluoborates now by writing for technical data and trial samples of the products that interest you. As always, General Chemical's skilled Engineering and Technical Servicemen are available to assist you in preparing for test or full-scale runs.

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Available now . . . extensive operating data on the Metal Fluoborates in the technical manuals outlined here. For copies, write or phone the nearest General Chemical Sales and Technical Service Office listed above.

Lead-Tin Alloy Plating MANUAL LT-1
Full description of the practical, economical fluoborate method for plating lead-tin alloys in any desired ratio (particularly low-tin ranges) with high degree of uniformity and minimum of control measures.

Zinc Fluoborate MANUAL ZF-1
Covers high-speed plating with Zinc Fluoborate electrolyte from which zinc is deposited at higher rate than from other acid baths. Also explains tank and barrel plating on cast or malleable iron.

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Metal Fluoborates BULLETIN 1015-A
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THE TOUGHER THE COMPETITION
THE BETTER YOU'LL LIKE

MO-MAX
HIGH SPEED STEELS

When you specify MO-MAX High Speed Steel for your cutting tools, you reduce your machining costs in two ways.

First, MO-MAX cutting tools deliver up to 20% **more performance.** Second, the weight per cubic inch of MO-MAX is 8% less than that of 18% tungsten steel. This means that more tools can be made from MO-MAX than from an equivalent weight of high tungsten steel.

You can cut your costs . . . strengthen your competitive position . . . by taking advantage of this **double economy.** Start using MO-MAX today! Phone or write one of these mills listed below.

Buyer's Guide to Brands of MO-MAX

"LMW"	Allegheny Ludlum Steel Corp.
"MOHICAN"	Atlas Steels Limited
"BETHLEHEM HM"	Bethlehem Steel Co.
"MO-CUT"	Braeburn Alloy Steel Corp.
"STAR MAX"	Carpenter Steel Co.
"MOLITE M-1"	Columbia Tool Steel Co.
"REX T-MO"	Crucible Steel Co. of America
"DI-MOL"	Henry Disston & Sons, Inc.
"HI-MO"	Firth-Sterling Steel Co.
"REX T-MO"	Halcomb Steel Co.
"MOGUL"	Jessop Steel Company
"TATMO"	Latrobe Electric Steel Co.
"MIDMAX"	The Midvale Co.
	St. Lawrence Alloys, Inc.
"S. T. M."	Simonds Saw & Steel Co.
"MO-TUNG"	Universal-Cyclops Steel Corp.
"8-N-2"	Vanadium-Alloys Steel Co.
"VUL-MO"	Vulcan Crucible Steel Co.

ONLY MO-MAX GIVES YOU *all* THESE ADVANTAGES

1 MO-MAX has superior cutting qualities. It is a happy combination of great toughness with high hardness.

2 The machinability of MO-MAX is unexcelled, particularly in grinding.

3 MO-MAX is economical. Its specific gravity is about 8% less than that of 18% tungsten steel. Thus for the same weight of high speed steel, 13 bars of MO-MAX are obtained as compared with 12 similar bars of an 18% tungsten steel.

4 In addition to the standard general-purpose composition of MO-MAX high speed steel, several special types have been developed for particular purposes. There are four with a high cobalt content, one high in vanadium and two that are especially suitable for hot die work.

5 MO-MAX was the first of the modern molybdenum high speed steels. For 13 years MO-MAX has demonstrated its superiority in cutting tools.

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Send for your copy of the MO-MAX Handbook, sixth edition. Get the full story about this remarkable steel, including easy-to-follow instructions on heat treating.

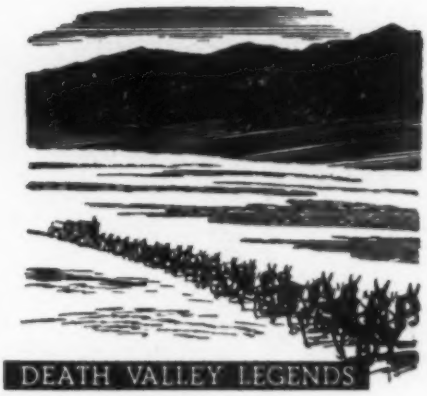
THE CLEVELAND TWIST DRILL COMPANY • 1242 East 49th Street • Cleveland 14, Ohio

ONE OF A SERIES OF STORIES ABOUT ALLOYING METALS . . . WHERE THEY COME FROM AND HOW THEY ARE USED

THE STORY OF BORON

CENTURIES OLD

1 As long ago as the sixteenth century, records show that borax, a source of boron, was exported to Europe from Central Asia through Constantinople and Venice. The Persians called it "burah" from which we took our word "borax." Boron was isolated in 1808 by both Davy and Gay Lussac.



DEATH VALLEY LEGENDS

2 Formerly mined in Death Valley, borax was hauled great distances by the legendary twenty-mule teams under adverse conditions of rugged topography and intense heat. Known to the housewife as a cleansing agent, borax is also used industrially in soldering, welding, and the making of enamels.

ACTIVE WHEN HOT

3 Unaffected by air at ordinary temperatures, boron is nevertheless extremely reactive at high temperatures, particularly with the elements oxygen and nitrogen. That's why it is used as a deoxidizer and degasifier by the metal industry. It is also used to refine the grain of aluminum alloys.

MUCH FROM LITTLE

4 Boron improves the hardenability of steels; only a minute amount of boron is necessary to give the desired results. To avoid complete oxidation of this small quantity, the boron must be protected by other strong deoxidizers, or it must be added to a completely deoxidized bath.

HEAVY DUTY AGENT

5 Electromet produces "Silcaz" and "Silvaz" alloys, containing other strong deoxidizers that will protect the boron when added to the molten steel. Boron-treated steels are used for heavy machine parts such as gears and shafts. The presence of boron improves the quality of certain high-speed tool steels.

For Alloy Users . . .

Electromet supplies ferroboron, manganese-boron, nickel-boron, and the special boron-containing alloys, "Silcaz" and "Silvaz." Constant research by Electromet has continually developed newer and better alloys. An explanation of Electromet's service to users of ferro-alloys, and descriptions of Electromet's products are included in the booklet, "Electromet Ferro-Alloys and Metals." Write to our Technical Service Department today for a copy.

ELECTRO METALLURGICAL COMPANY
Unit of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.

ELECTROMET Ferro-Alloys and Metals are sold by Electro Metallurgical Sales Corporation and Electro Metallurgical Company of Canada, Limited, Welland, Ontario.

"Silcaz" and "Silvaz" are trade-marks of Electro Metallurgical Company.

Electromet
TRADE MARK
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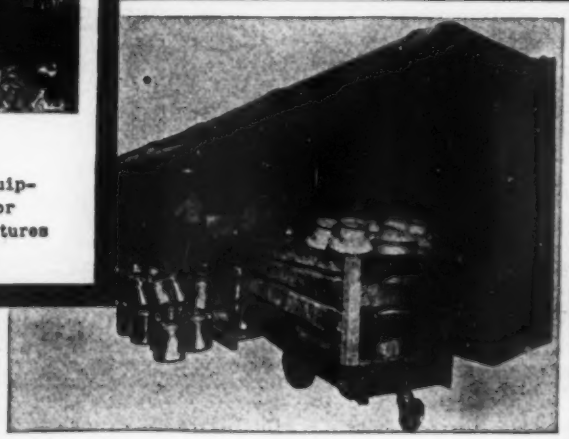
A. Because they're *faster, simpler &* more *serviceable* for industrial applications

CHEMICAL

For laboratory and process work, Wheelco Capacitrols permit closer temperature control and greater flexibility, because of their "Electronic Control Principle" (no mechanical linkage).

DIE CASTING

Wheelco Electronic Capacitrols are standard equipment in die casting plants over the country, for accurate and dependable control of the temperatures of the casting metal.



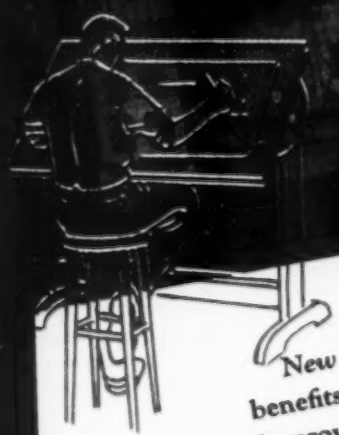
TINNING

For coating, babbitting and other operations using tin, Wheelco Electronic Capacitrols speed production, with less loss of tin, by closer and more reliable control of tinning temperatures.

WHEELCO INSTRUMENTS COMPANY
835 W. Harrison St., Chicago 7, Ill.

WHEELCO *Electronic* CONTROLS

ANTICIPATE YOUR FURNACE REQUIREMENTS



New Salem furnaces will give you any or all of the following five benefits: (1) Increased production, (2) Less material handling, (3) Improved product, (4) Decreased costs, (5) Minimum maintenance operating delays.

Functional engineering details can be negotiated now in anticipation of your desired delivery date.

You will find it well worth your while to anticipate your furnace requirements with Salem at this time. Tell us what you have in mind now.

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Engineered Heat

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Problem-solving is a major task for men in the metal industry. It is not a too difficult task if you keep this in mind: you need not know every answer—but KNOW where you can find the answer.

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(Vols. 1 and 2)

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If you do not have Volume 1, there are a few of these books available at $15.00. These reference volumes are a must for every library. Write for yours today and make this the beginning of a full set.

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CORROSION OF METALS

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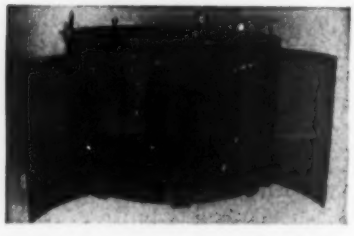

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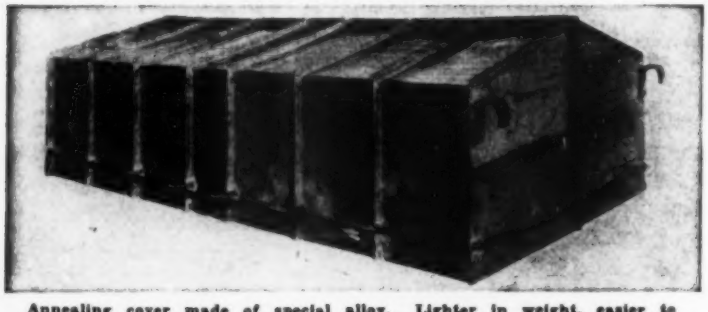

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0.010" to 0.035"	DU PONT ACCELERATED SALT with Graphite Cover	1500 to 1650	18-22	ACCELERATED SALT or ⅓ HEAT TREATING SALT No. 6 plus ⅔ ACCELERATED SALT	ACCELERATED SALT
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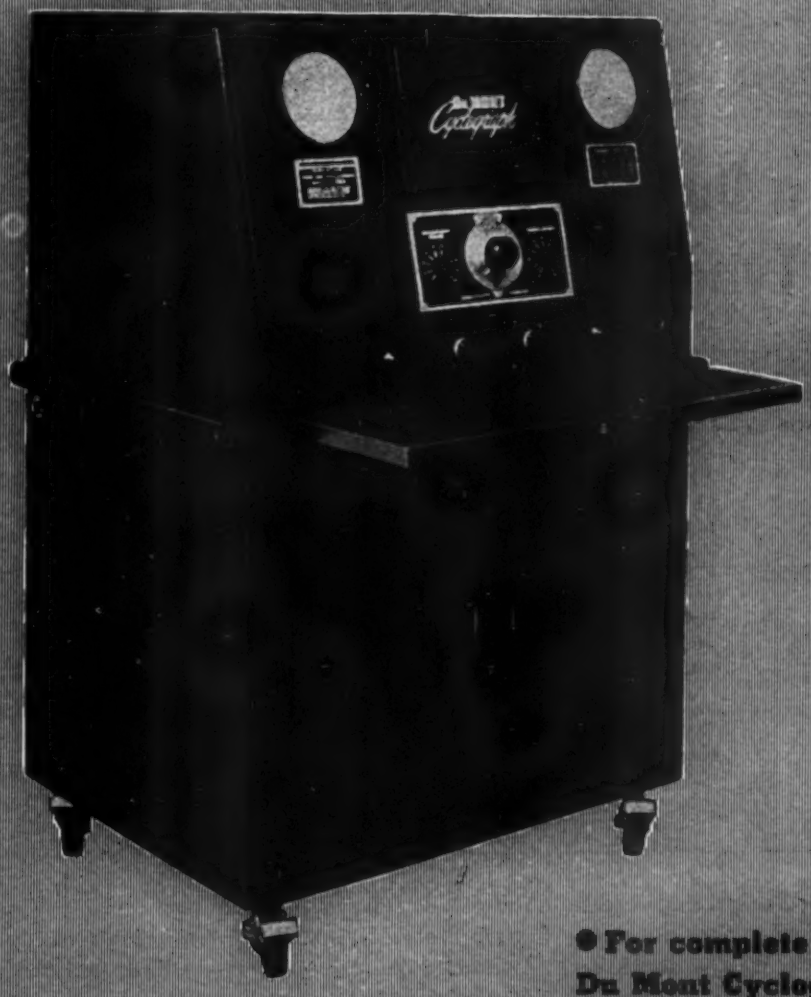

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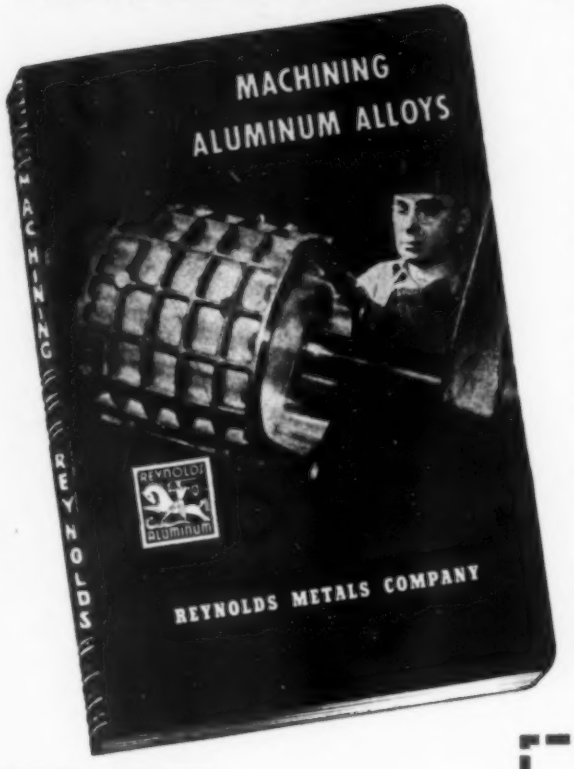

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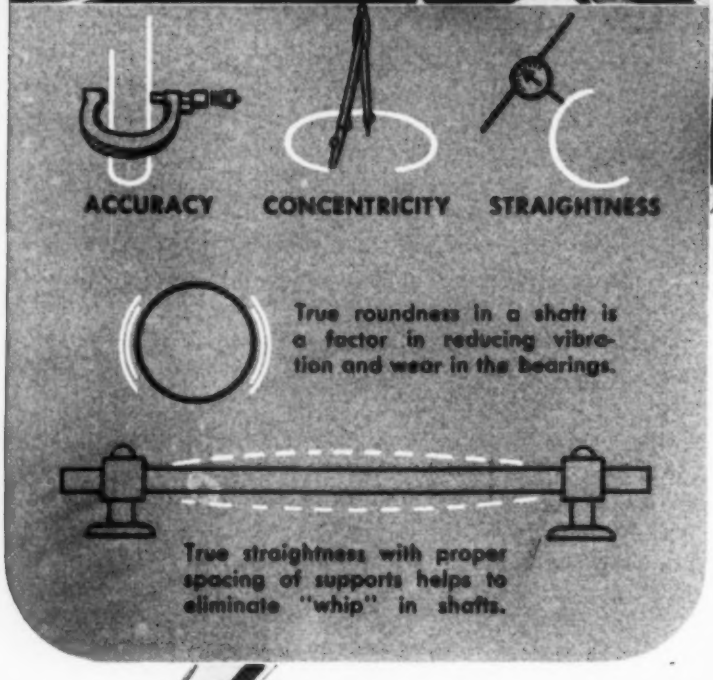
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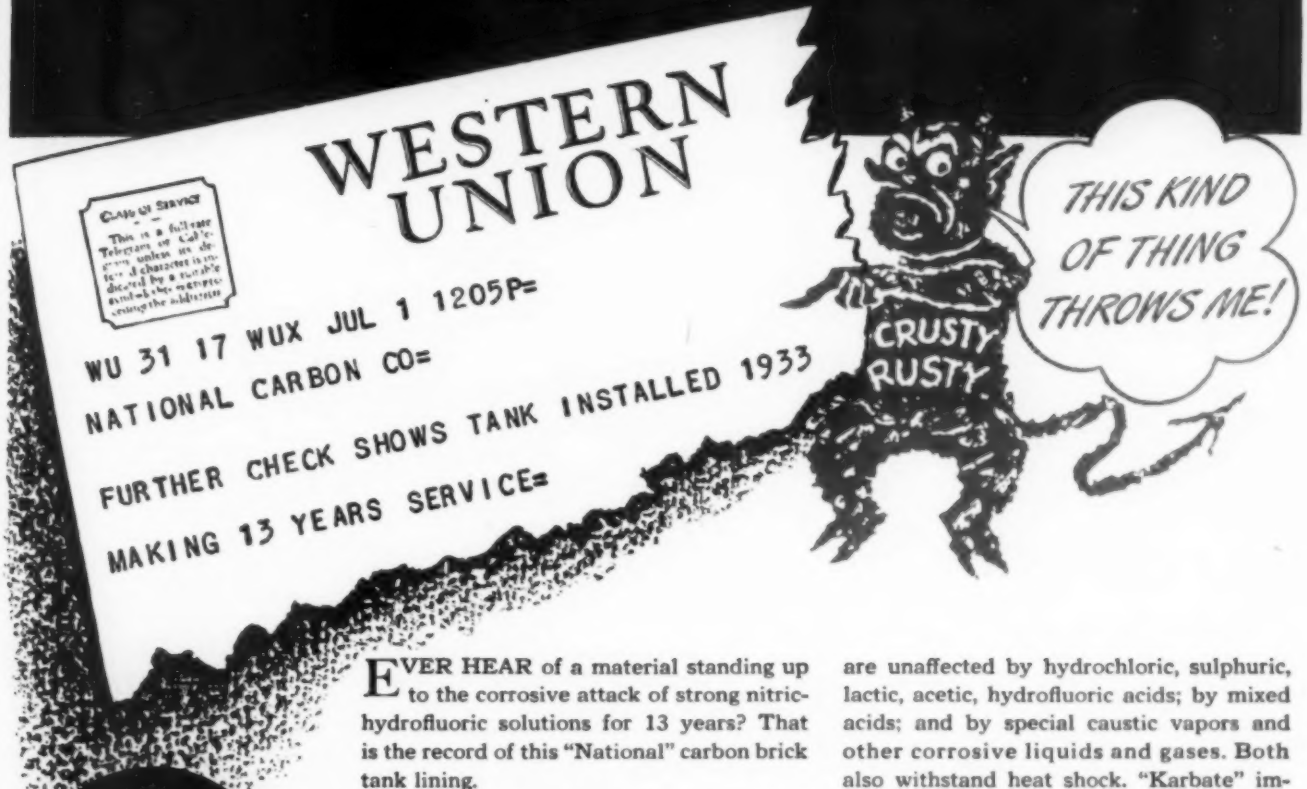
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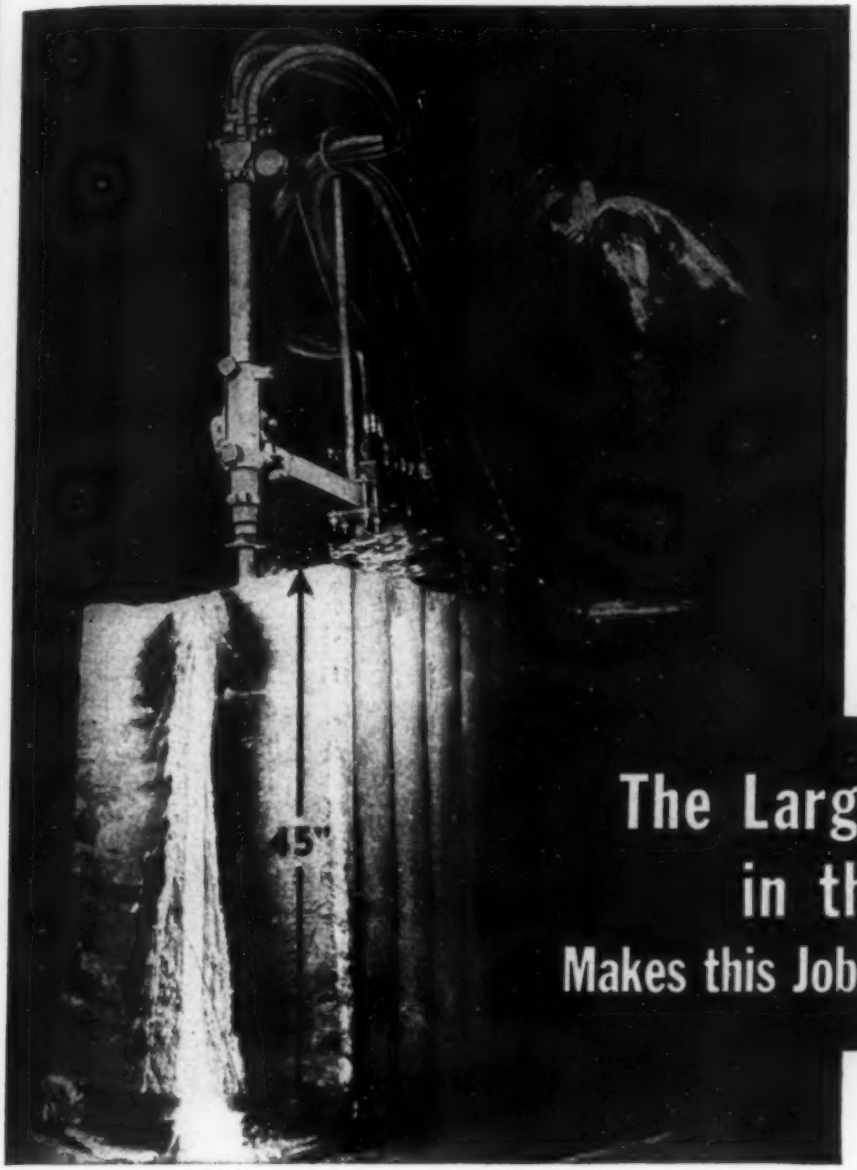

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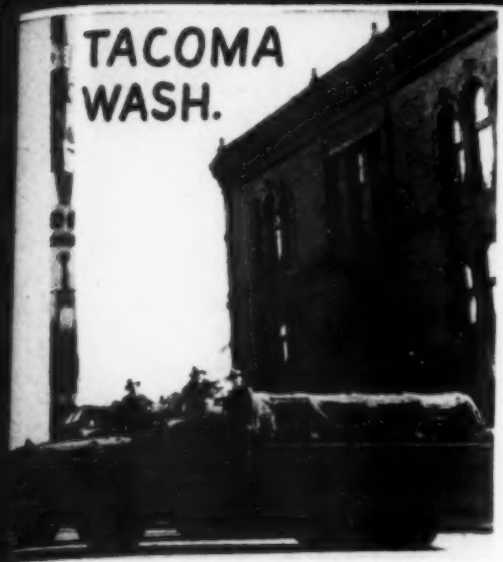

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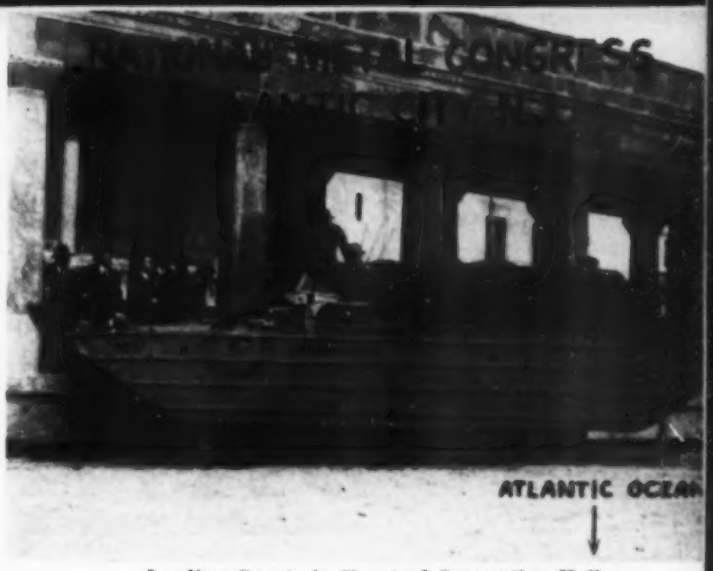
Tacoma, Wash. To Atlantic City Metal Show



nd Bob Allen Leave Tacoma, Wash., Nov. 3rd

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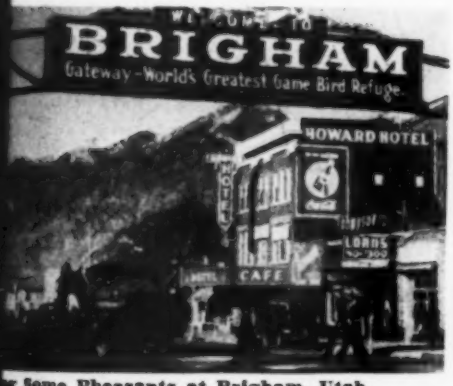

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Experience "Invasion" Ride Through Atlantic Surf

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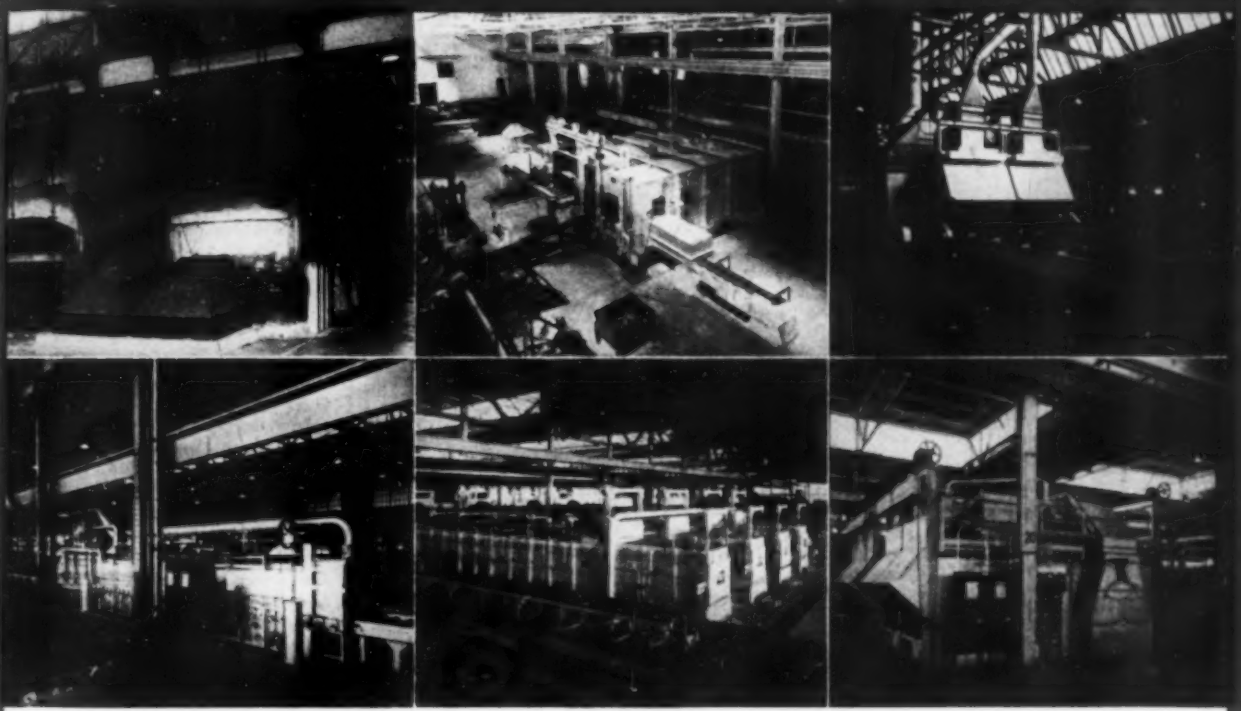

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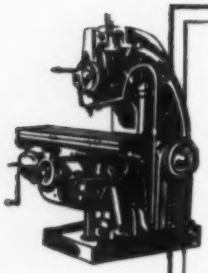

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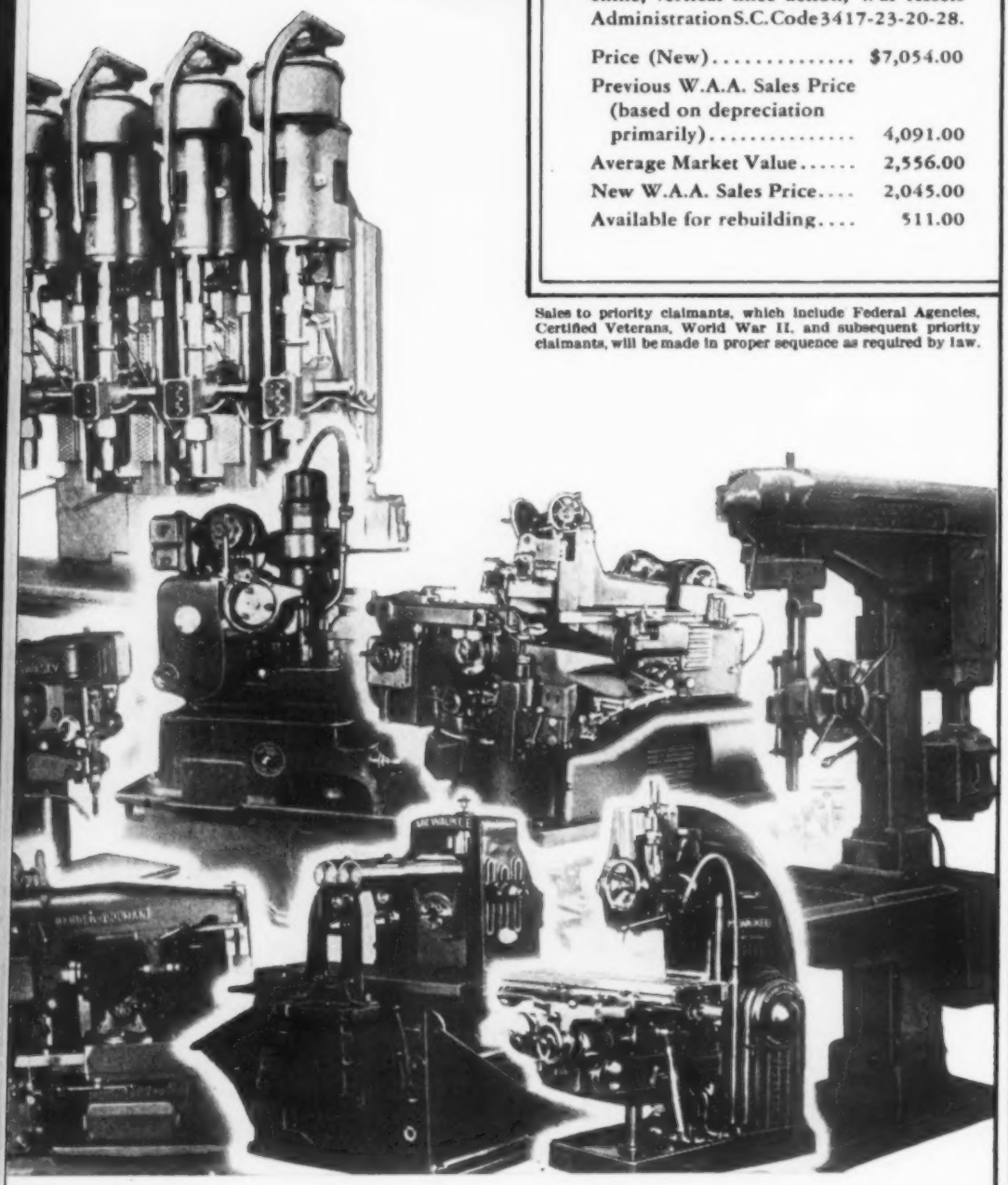

31 TYPES OF GENERAL PRODUCTION TOOLS REPRICED

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- Chucking Machine—Automatic, Vertical, Multiple Spindle Type
- Chucking Machine—Single Spindle Automatic, Horizontal Turret Type Machine
- Chucking Machine—Six Spindle Automatic, Horizontal
- Drilling Machine or Drill Press—Bench or Floor, Single or Multiple Spindle
- Gear Cutting Machine for Straight Bevel Gears, (Not Planer Type)
- Gear Hobber—Horizontal
- Gear Hobber—Vertical, Universal
- Gear Shaper—For External Spur Gears Only
- Gear Shaper—For Spur Gears, External or Internal
- Gear Shaper—For Spur and Helical Gears, External and Internal
- Gear Tooth Shaver—For External and Internal Gears (Rotary Type Machine)
- Gear Tooth Grinder—Generating Type, for Spur and Helical Gears
- Gear Tooth Grinder—For Spur Gears, External and Internal (Formed Wheel Type Machine)
- Grinders—Centerless
- Grinder—Crank Pin Grinders
- Grinders—Plain External Cylindrical Grinder
- Grinder—Internal, Cylindrical, Automatic Sizing
- Grinder—Internal Cylindrical (Hydraulic Feed Machine)
- Grinder—Internal Cylindrical, Hydraulic Feed, for Hole and Face Grinding
- Grinder—Surface, Rotary Table Type
- Lathe—Multiple Tool, Not Automatic, Manufacturing Type Production Lathe
- Milling Machine—Automatic and Manufacturing Knee Type
- Milling Machine—Plain Bed Type, Horizontal Spindle Machines
- Milling Machine—Vertical, Knee Type (Not Including Bench Type)
- Polishing and Buffing Machine—Bench and Floor
- Profiling Machine—Vertical, Fixed Bed Type, Single and Multiple Spindle
- Tapping Machine—Vertical, Single or Multiple Spindle
- Thread Grinding Machines
- Thread Milling Machine
- Turret Lathe—Ram Type, Plain and Universal

MACHINE TOOL
SALES DIVISION

When fabricating Stainless

REWELDING

IS

COSTLY

you will agree . . .

Hours spent welding it over again are an unnecessary cost which can be eliminated. Your decision to use Arcos electrodes for your stainless or alloy welding job is a long step toward eliminating non-productive man hours. When you order Arcos, you receive electrodes which, in the hands of a competent welder, deposit the sound weld metal you need. Sound welds—physically and chemically right for the job—the first time and every time, eliminate costly chipping and rewelding. Specify Arcos and avail yourself of the knowledge and a product born of fourteen years' experience in making stainless and special alloy electrodes.

WHEN YOU USE ARCOS ELECTRODES—YOU WILL AGREE

ARCOS

ARCOS CORPORATION • 306 GULF BUILDING, PHILA. 2, PA.

BURRELL • GAS ANALYSIS APPARATUS

from Plant Control

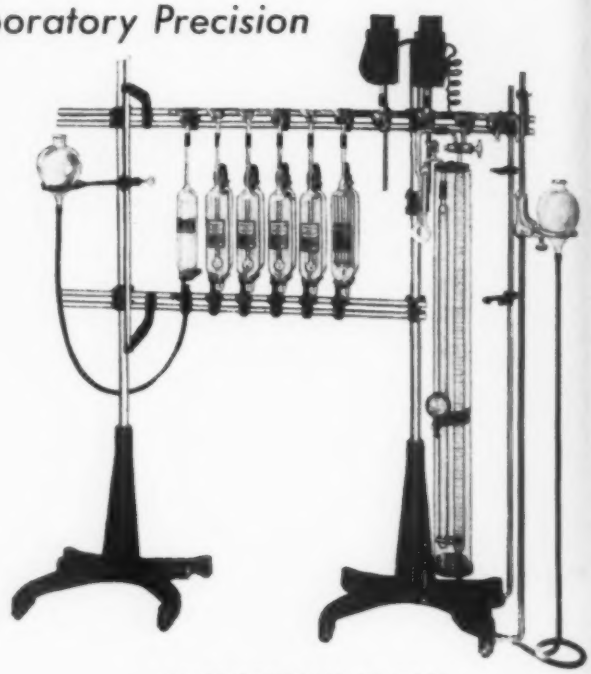
. . . to Laboratory Precision

APPARATUS for the analysis of gases by absorption and combustion methods are divided into two general types, laboratory and portable models.

Laboratory models are more precise while portable models are relatively smaller, more compact and simpler to manipulate.

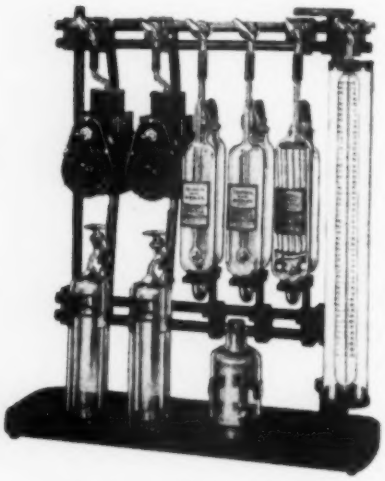
The popular Build-Up* frame for both laboratory and portable models comprises standardized parts — clamps, bases, rods, supports — which can be assembled to carry any selection of standard gas analysis glassware. This feature permits the analyst to choose an apparatus exactly to fit his needs and just as important to quickly alter the assembly should necessity arise.

* Trademark registered U.S. Patent Office.



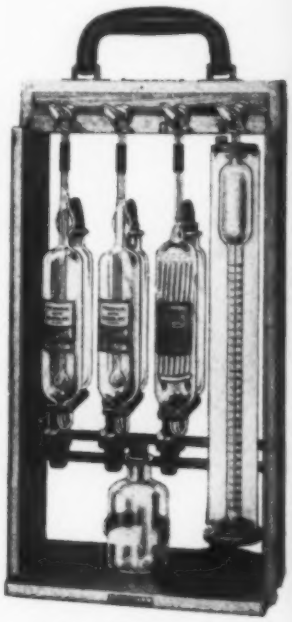
A LABORATORY BUILD-UP MODEL FOR PRECISION ANALYSIS

Heavy bases in the Build-Up laboratory models provide stability and preclude the necessity of fastening to the bench top. Aluminum cross tubes are extra long to permit expansion of the apparatus if desired. Glassware may be added or removed without dismantling the frame.



A PORTABLE BUILD-UP MODEL FOR PLANT CONTROL

The Flue Gas Analyzers are designed especially for the analysis of flue or stack gases, but may be used wherever three gaseous components are to be determined by absorption.



A FLUE GAS ANALYZER FOR STACK ANALYSIS

Portable Build-Up models are mounted on a stout oak base and may be had with or without the carrying case.

For complete information on all types of Burrell Gas Analysis Apparatus write for Catalog 80.

SCIENTIFIC APPARATUS BURRELL LABORATORY CHEMICALS

BURRELL TECHNICAL SUPPLY COMPANY

1942 FIFTH AVENUE **PITTSBURGH 19, PA.**

Research leadership back of every Ingot

A practical, working knowledge of your problems . . a superior product to meet them. These are the standards by which Apex Ingot is made . . the reasons why foundrymen everywhere say,

"It's best in every test from Ingot to Casting!"

Apex Smelting Company

2537 WEST TAYLOR STREET • CHICAGO 12, ILLINOIS

CONSULT THESE

Use *Steel* Castings

Specify Steel Castings for:

Aeronautical
Agricultural Machinery
Automotive
Bearing
Boiler, Tank & Piping
Bridge
Chemical & Paint Works
Compressors (Pneumatic)
Conveyor & Material Handling
Crushing Machinery & Cement Mill
Dredge
Electrical Machinery & Equipment
Elevator
Engine
Food Processing & Packing Plant
Foundry Machinery & Equipment
Gas Producer & Coke Oven
Gears
Heat Treating Furnace & Equipment
Hoist & Derrick
Iron & Steel Industries
Metallurgical Machinery
Mining Machinery & Equipment
Oil or Gas Field & Refinery
Ordnance
Overhead Crane & Charging Machine
Paper Mill
Printing Press
Pump
Railroad
Refractory, Brickyard & Ceramic
Refrigeration Machinery
Road & Building Construction
Rubber Mill
Ship & Marine
Shoe Machinery
Smelting Plant
Spray Painting Equipment
Steam Turbine
Street, Elevated & Subway Cars
Textile Machinery
Valves, Fittings & Piping
Well Drilling Equipment

Now is the time to put *your* product to the steel casting test.

If your product is made of metal, check it for quality . . . for efficient production . . . for strength and durability against the many advantages of cast steel components.

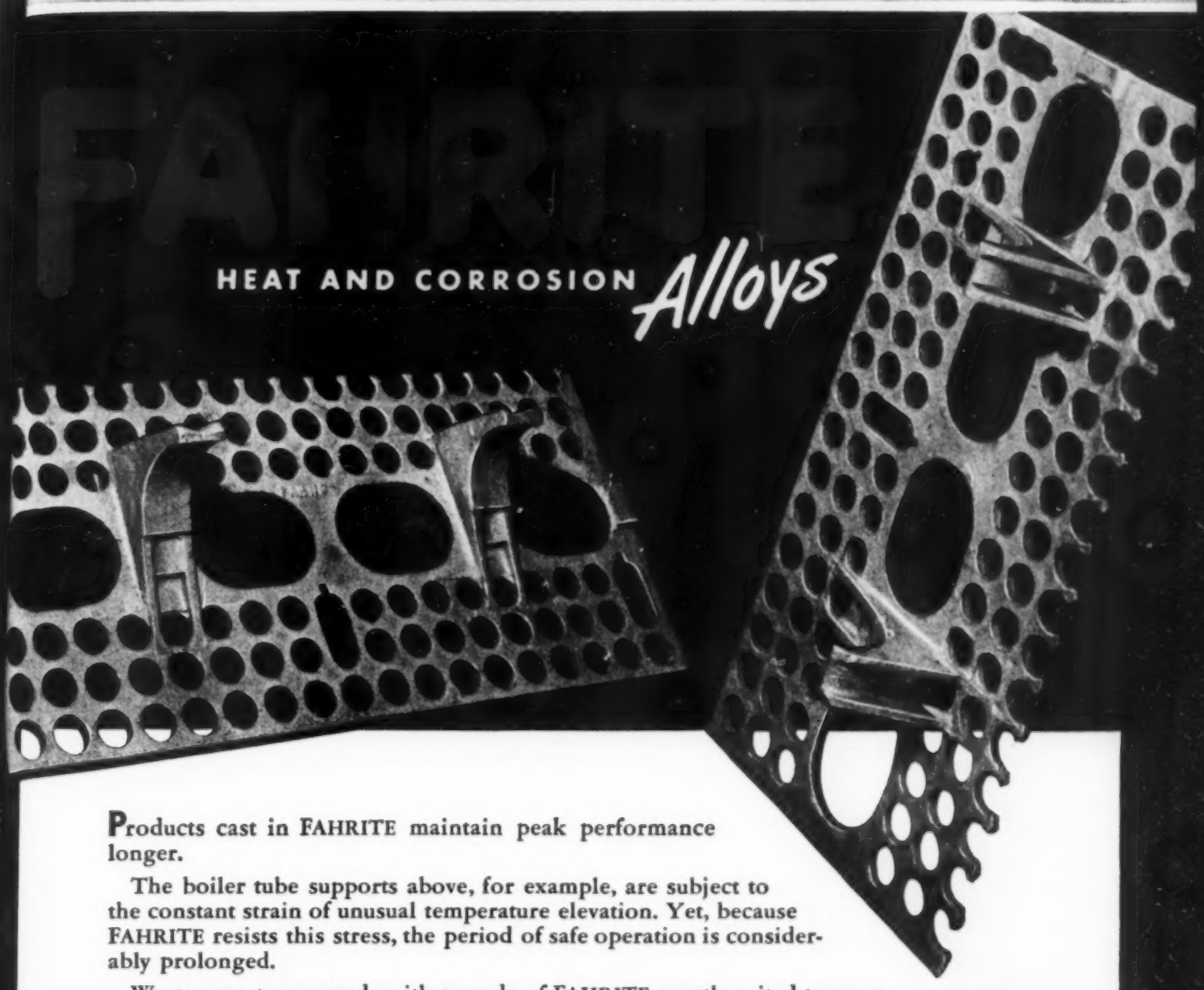
You will find a readiness on the part of each steel foundry listed at the right to work with you in the development and improvement of the metal product you manufacture—or plan to manufacture.

New foundry techniques offer many advantages, including greater strength, greater ductility, precise mechanical properties and closer tolerances.

Put in a call today to the foundry nearest you.

Where high temperatures are sustained...

HEAT AND CORROSION *Alloys*



Products cast in FAHRITE maintain peak performance longer.

The boiler tube supports above, for example, are subject to the constant strain of unusual temperature elevation. Yet, because FAHRITE resists this stress, the period of safe operation is considerably prolonged.

We can meet *your* needs with a grade of FAHRITE exactly suited to your present operating conditions. Write for catalog which gives complete details.

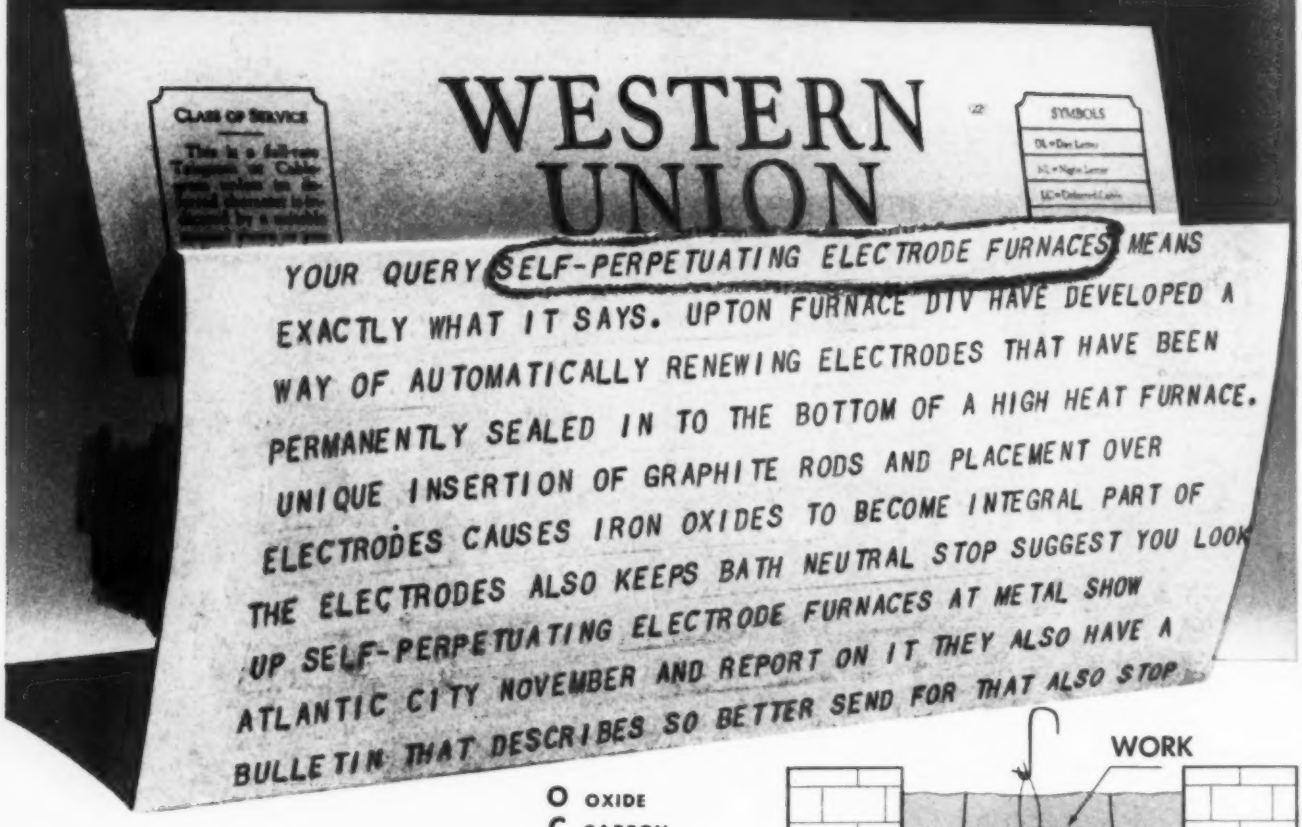
THE OHIO STEEL FOUNDRY COMPANY

SPRINGFIELD, OHIO • *Plants at Lima and Springfield, Ohio*

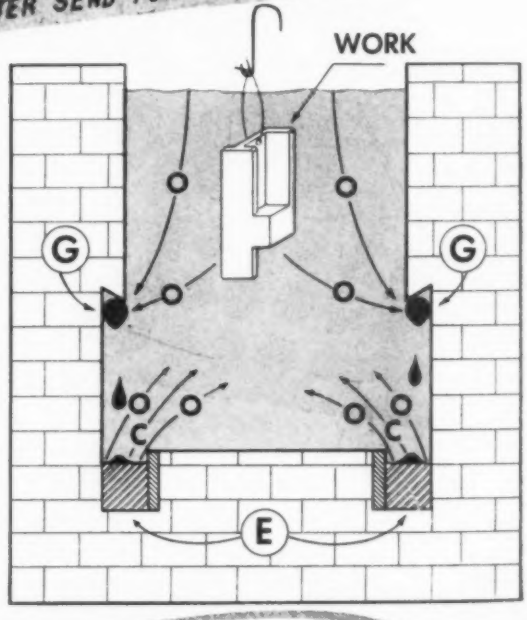
ENGINEERS • FOUNDERS • MACHINISTS

Announcing the NEW

SELF-PERPETUATING ELECTRODE FURNACES


WESTERN UNION
CLASS OF SERVICE
SYMBOLS
YOUR QUERY SELF-PERPETUATING ELECTRODE FURNACES MEANS EXACTLY WHAT IT SAYS. UPTON FURNACE DIV HAVE DEVELOPED A WAY OF AUTOMATICALLY RENEWING ELECTRODES THAT HAVE BEEN PERMANENTLY SEALED IN TO THE BOTTOM OF A HIGH HEAT FURNACE. UNIQUE INSERTION OF GRAPHITE RODS AND PLACEMENT OVER ELECTRODES CAUSES IRON OXIDES TO BECOME INTEGRAL PART OF THE ELECTRODES ALSO KEEPS BATH NEUTRAL STOP SUGGEST YOU LOOK UP SELF-PERPETUATING ELECTRODE FURNACES AT METAL SHOW ATLANTIC CITY NOVEMBER AND REPORT ON IT THEY ALSO HAVE A BULLETIN THAT DESCRIBES SO BETTER SEND FOR THAT ALSO STOP

O OXIDE
C CARBON
E ELECTRODE
G GRAPHITE ROD



Oxides form in the bath, from contact with the atmosphere at the surface, from the work, and from absorption of oxygen from electrodes.

1. Electrodes give up oxygen, waste away.
2. Oxides circulating through bath contact graphite rod.
3. Oxides are reduced to metallic state in contact with graphite rod.
4. Increased carbon content reduces melting point of oxide.

Oxide droplets form, fall on electrode. Droplets begin giving up carbon, harden on electrodes, become integral part of electrode.

Ask for complete information on this process and its use in your heat treating.

Upton ELECTRIC FURNACE DIV.

7435 BEVERLY AT GREEN • DETROIT 17, MICHIGAN

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Use the prepaid postcard on this page to obtain the helpful literature described on these two pages.

851. Precision Casting Equipment

Kerr Mfg. Co.—Specialised materials and equipment necessary to precision casting are illustrated and described to show metallurgical engineers the great possibilities of this process for volume production.

852. Salt Bath Conveyor

A. F. Holden Co.—40-page booklet covers simplified conveyor system for conventional heat treating, austempering, martempering, flow heat treatment, liquid carburizing and cycle-annealing. Drawings are used to illustrate.

853. Induction Heating

Ohio Crankshaft Co.—59-page booklet covers general history, principles and application of induction heating. Deals specifically with many of induction heating's most technical considerations. Well illustrated with pictures, charts and graphs.

854. Roller Hearth Furnaces

Surface Combustion Corp.—4-page bulletin describes prepared atmosphere roller hearth furnaces for ferrous and nonferrous bars, tube and strip. Illustrated, the bulletin cites such features as virtual elimination of air infiltration, accuracy of roller alignment, etc.

855. Welding Technique

Ampco Metal, Inc.—Revised 16-page edition of "Ampco-Trode Welding Technique" features welding of aluminum bronze electrodes. Contains comprehensive weldability chart for copper-base alloys, listing 33 bronze alloys; 22 photographs.

856. Heat Treating Data Book

Sunbeam Stewart Industrial Furnace Div.—Condensed, illustrated data book—vest pocket size—contains quick-reference answers to many heat treating and metal processing questions. 72 pages of charts, tables, diagrams, factual data on steel specifications, heating time allowances, hardness and tempering conversion tables.

857. Soldering Fluxes

American Chemical Paint Co.—Flosol soldering fluxes are the subject of this technical service data sheet. Applications for use in soldering sheet metal and other products constructed of carbon and stainless steels, brass, copper, tin, terne plate, zinc and galvanized iron are described.

858. Deep Drawing Magnesium

Revere Copper and Brass, Inc.—12-page article illustrates the methods used and the results obtained in the drawing of magnesium. Alloys of magnesium can be drawn from three to four times as deep in one operation as can steel or aluminum, it is said.

859. Box and Pot Furnaces

Dempsey Industrial Furnace Corp.—8-page illustrated booklet describes box and pot type oil and gas fired furnaces. Specifications and temperatures are listed.

860. Instrument Recording

44-page booklet describes photographic recording materials for use with cathode ray tube oscillographs, galvanometer oscillographs, and similar instruments. Contains information on physical and photographic properties of films and papers and on processing procedures, equipment and materials.

861. Ammonia in Metal Treating

Mathieson Alkali Works—40-page booklet comprehensively discusses ammonia in metal treating both as a furnace atmosphere and as a source of pure hydrogen; expanded during the war, use of ammonia is now established as an important metallurgical operation. Applications in connection with case hardening, copper brazing, powder metallurgy and welding are described. Properties and handling are discussed.

862. Polishing Cloths

Burrell Technical Supply Co.—Handy file size brochure contains information on polishing cloths and abrasives. Folder lists polishing cloths according to their catalog number, with samples arranged in order of their quality. Each sample indicates size and price.

863. Gas Carburizing

Holcroft & Co.—4-page bulletin describes gas carburising furnaces for mass-production industries; briefly describes controlled-atmosphere gas carburising process and outlines inherent advantages. Possible furnace design features are listed.

864. Pig Iron

Keokuk Electro-Metals Co.—High silicon pig iron for steel plants and foundries is described in new book, "Electro-Silvery". Scores of photographs, seven beautiful oil paintings, and interesting informative text tell about Keokuk's special methods of processing and casting high silicon pig iron.

865. Thermometers

Brown Instrument Co.—20-page booklet describes rectangular case thermometers and pressure gauges. Vapor, gas and mercury actuated thermometers and gauges are illustrated, with large cut-away illustration featuring design improvements.

866. Free Machining Die Steel

Vanadium-Alloys Steel Co.—8-page booklet describes "Speed-Cut", new die steel made with a composition particularly successful for plastic molds and for die casting dies for white metal alloys. Novel feature is free machining quality, which permits hardening steel prior to machining.

867. Induction Heating Machine

Gordon Electronics, Inc.—4-page leaflet describes the new Trigatron, induction heating machine for hardening, brazing, soldering, heat treating and melting.

868. Vitrobond Refractory

Johnson Fuller Co.—4-page leaflet describes Vitrobond as a highly refractory, self-vitrifying, high temperature furnace, fire box and crucible coating made from a zirconium silicate base with other high melting oxides. Vitrifies at 2090 deg. F. and will stand 3850 deg. F. before fusing again.

869. Transformers

Surges Electric Co.—4-page leaflet describes dry type air-cooled transformers, with many illustrations to show wide range of applications.

870. Electric Furnaces

Sentry Co.—12-page booklet describes electric furnaces and Sentry diamond block method of atmospheric control for hardening high speed steel.

871. Betatron

Allis-Chalmers Mfg. Co.—48-page booklet is a compilation of articles on the application of the Betatron, which accelerates electrons by magnetic induction making possible the production of higher energy X-rays than is practical by direct application of the accelerating potential.

872. Stainless Steel Handbook

Allegheny Ludlum Steel Corp.—100-page handbook of stainless steels presents a well-indexed guide to properties, characteristics and applications of many stainless products. Charts and tabular matter are included for quick, easy reference.

873. Magnetic Testing

Allen B. DuMont Laboratories, Inc.—8-page leaflet describes the use of the Ferrograph, developed to provide a simple and convenient method of comparing ferrous materials as to chemical analysis and heat treatment.

874. Immersion Pyrometer

Pyrometer Instrument Co.—4-page leaflet illustrates the new immersion pyrometer for nonferrous metals. Features cited are—self-contained, quick-acting, dependable, direct reading, 4½" indicator.

875. Die Steels

Kropp Forge Co.—8-page bulletin contains complete particulars on each of five special tool and die steels, including analyses, values and applications.

876. Gas Cutting

Air Reduction Sales Co.—12-page article discusses special oxyacetylene machine cutting applications in detail; describes uses of electronic tracing device; cutting of new stainless steels; use of hot cutoff machines, etc.

877. Hardening

American Cyanamid Co.—New data sheet discusses hardening of high speed steel, saying four main types of high speed should be treated in four steps; gives recommended salt mixture and temperature range of each. Aero brand case hardening compounds are described in two additional data sheets.

878. Carburizing Steels

Vanadium Corp. of America—Chromium-Vanadium carburising steels and their modifications is only one of several interesting articles in Vol. V, No. 1, of The Vancoram Review. Others deal with cutlery, locomotive modernization, vanadium data sheet, and vanadium in gray iron castings.

879. Alloy Steels

Carpenter Steel Co.—New program of simplification in selection of alloy steels is outlined in 10-page booklet, "2 Steels Simplify Your Alloy Needs". Claimed that two steels meet 95% of users' alloy steel requirements.

880. Pressure Gauge

W. C. Dillon & Co., Inc.—Mechanical pressure gauge is described in new bulletin. Features include high accuracy, light weight, compactness, various capacities, precision.

881. Heating and Melting

Ajax Electrothermic Corp.—8-page booklet describes induction heating and melting, including principles and advantages; shows many ways to use high frequency to speed production, hold closer tolerances in melting, heating for forging, brazing, etc. Data included to assist in proper selection of equipment.

882. Fatigue Testing

Baldwin Locomotive Works—New bulletin gives specifications and full details of Sonntag model SF-10R rotating beam fatigue testing machine; produces constant bending moment from 0 to 10,000 inch-pounds on round specimens as large as one inch diameter.

883. Kennametal Characteristics

Kennametal Inc.—Interesting 16-page booklet describes the general nature of Kennametal compositions, brings together the information as to properties for more effective application. Micrographs, physical and mechanical properties tables, corrosion resistance, simple and complex shapes, and finishes are discussed.

FIRST CLASS
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Cleveland, Ohio

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METAL PROGRESS
7301 Euclid Avenue
CLEVELAND 3, OHIO

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

884. Circular Products

Bethlehem Steel Co.—32-page booklet gives illustrated and typical advantages of using rolled and forged circular products. Details of many applications include gear blanks, industrial wheels, brake drums, turbine rotors, molds and rings, pistons, sheaves, etc.

885. Carburizer-Nitrider

Hevi Duty Electric Co.—Handsome 32-page color booklet describes and pictures the Hevi Duty Carburizer-Nitrider which provides circulation of furnace atmosphere up to 1850 deg. F.; provides best of temperature uniformity through multiple zoning; can be operated to produce accelerated cooling outside the furnace with maintained protective atmosphere. Carburizing processing gases and procedure and the nitriding procedure are discussed.

886. Pipe and Fitting Chart

Tube Turns (Inc.)—Handy new chart of pipe and fitting materials deals with carbon, intermediate alloy, stainless and special analysis steels—covers ASTM specifications, chemistry, service limitations and welding procedure.

887. Portable Pyrometer

Wheelco Instruments Co.—4-page bulletin describes complete line of portable pyrometers. Handsome walnut carrying case models for single and double scales are available with or without multiple rotary switches. Full information on extension type lance pyrometer, and portable pyrometer kit is pictorially illustrated.

888. Temperature Control

Claud S. Gordon Co.—4-page color bulletin gives complete technical description of Xactline temperature control. Instrument provides close temperature-variation control; variation as low as 1/5 of a degree F. and power on-off cycles as short as three seconds have been attained.

889. Dust Control

American Foundry Equipment Co.—8-page leaflet describes dust collecting equipment, featuring cloth bag type dust collectors. Three models are available ranging from 270 C.F.M. up.

890. Welding Control

General Electric Co.—12-page bulletin comprehensively discusses the importance of control in resistance welding. Reviewing the need for precision application of heat and pressure and of mechanical operations, leaflet points out that automatic control is required, and outlines several control devices.

891. Tank Rheostats

Columbia Electric Mfg. Co.—4-page leaflet describes cast grid type tank rheostats for electroplating control. Standard sizes, 15 to 5000 amperes, 1 to 6 volt drop, as specified; tapered or untapered design. Rheostat enables plater to have accurate control of tank current under varying load conditions.

892. Refractories

Chas. Taylor Sons Co.—12-page bulletin discusses Taylor Zircon refractories for high temperature service and special applications. It is the first complete outline written on Zircon refractories and their application to various industries.

893. Aluminum Alloys

National Smelting Co.—Convenient 16-page file folder gives comprehensive data on Ternalloy, a series of aluminum base alloys in the aluminum-magnesium-zinc system. In each of these alloys an aluminum-magnesium-zinc phase or compound is present, which—together with the presence of other alloying elements carefully proportioned—affords unusual properties to the alloys.

894. Hard-Facing Electrode

Stoody Co.—New, improved coated Stoody self-hardening wear-resistant electrode for hard-facing all heavy equipment subjected to earth abrasion and impact is fully described in circular. New extruded flux coating improves welding characteristics and simplifies application.

895. Cold Testing

Bowser, Inc., Refrigeration Div.—Laboratory units for testing and processing at temperatures as low as —100 deg. F. are pictured in 4-page leaflet. Units provide controlled temperature, altitude and relative humidity over a wide range of operations. Effects of treatment may be noted through inspection window.

896. Laboratory Supplies

Wilkens-Anderson Co.—Wide range of laboratory supplies and accessories are illustrated and described in the 20-page Waco Catalyst, Vol. 7, 1946.

897. Electronic Alloys

Westinghouse Electric Corp.—For engineers and designers in communications, electronics, and other fields, a guide to the properties and applications of 18 recent metallurgical developments is presented in a new 48-page booklet.

898. Cutting Fluids

D. A. Stuart Oil Co.—A 13-page booklet version of a paper entitled "Cutting Fluids, an Appraisal and an Apology" presented before the Cincinnati Chapter of the A.S.M.E.

899. Alloy Price List

Michigan Steel Casting Co.—New price book, effective June 1, covers warehouse stocks of heat and corrosion resistant alloys.

900. Cadmium Plating

E. I. DuPont de Nemours & Co., Inc.—A complete manual for operation and maintenance of cadmium plating solutions contains 12 pages of helpful facts on this operation.

901. Al Powders, Pastes

Reynolds Metals Co., Inc.—Aluminum powders and pastes have an interesting background which is well told in an attractive 20-page illustrated folder.

902. Stainless Data

Peter A. Frasse & Co., Inc.—New data chart of condensed heat treating data on 24 different grades of stainless steel has been condensed to a single, file-sized card.

903. Organic Coatings

United Chromium, Inc.—16-page booklet covers the sources, properties and applications of the many resins used in synthetic lacquers and protective coatings.

904. Retort Furnaces

W. S. Rockwell Co.—Revolving retort furnaces for annealing, bright annealing, hardening and drawing are illustrated and described in new literature.

905. Die Casting Machines

Hydropress, Inc.—8-page, two-color booklet contains fine illustrations of Hydropress cold chamber die casting machines and shows products and operations.

906. Steel Pictures

Joseph T. Ryerson & Son, Inc.—8-page newspaper size rotogravure paper consisting almost entirely of steel application pictures provides interesting coverage of steel uses.

907. Machining Stainless

Rustless Iron & Steel Div.—84-page booklet contains practical information on cutting speeds, feeds, tooling, lubrication and relative machinability of the various stainless grades.

908. Stainless Correlation

Arcos Corp.—A large size data sheet, folding into an 8¼" x 11" cover, lists every well-known stainless steel by trade name with the proper Arcos alloy eldctrode for welding each steel.

909. Forgings Reference

Steel Improvement & Forge Co.—A reference booklet on forgings has been published for the use of design engineers, production executives and metallurgists that describes the equipment, tools, materials and forging techniques used in forging metals in closed impression dies.

910. Cutting Oils

Gulf Oil Corp.—Interesting presentation of Gulf cutting oils is made in this booklet which includes a helpful machining guide. Vital advantage in machining efficiency may produce substantial cuts in unit production costs because every Gulf cutting oil has specific properties insuring better performance on certain types of machining jobs.

911. Precision Casting

Austenal Laboratories, Inc.—8-page new booklet explains and illustrates unique process of precision casting which makes possible castings of intricate shape and design from high melting point, non-machinable alloys.

912. Furnace Electrodes

International Graphite & Electrode Corp.—Helpful pointers on the use and care of furnace electrodes are presented in word and picture in an 8-page booklet.

913. Otiscoloy

Jones & Laughlin Steel Corp.—A high-tensile, low-alloy steel manufactured to meet the need for a readily weldable and easily fabricated corrosion resistant steel of substantially greater strength than the standard carbon structural steels is described in a 16-page two-color booklet.

914. Mechanical Tubing

Ohio Seamless Tube Co.—Latest revised list of mechanical tubing mill stock containing brief specifications for each type of tubing together with the total number of feet of tubing now in stock is available.

915. Engineered Heat

Salem Engineering Co.—Designed for engineers and production men, a new 16-page booklet contains descriptive information on circular soaking pits, various types of heat furnaces, and auxiliary equipment developed by Salem.

916. Testing Machines

Tinius Olsen Testing Machine Co.—A handsome 60-page booklet covers the entire line of Universal Testing Machines for tension, compression, and flexure testing.

917. Induction Heating

Lepel High Frequency Laboratories, Inc.—New 32-page catalog of Lepel high frequency induction heating units, well illustrated with photographs and drawings, gives much helpful data in non-technical language on the subject of induction heating. Typical applications are illustrated in striking photographs.

918. Die Casting Design

Lester-Phoenix, Inc.—Herbert Chase has written an authoritative article on die casting design which is available in conjunction with helpful data on die casting.

METAL PROGRESS

7301 Euclid Avenue, Cleveland 3, Ohio

December, 1946

851	867	883	899	915
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Please have literature circled at the left sent to me.

Name _____ Title _____

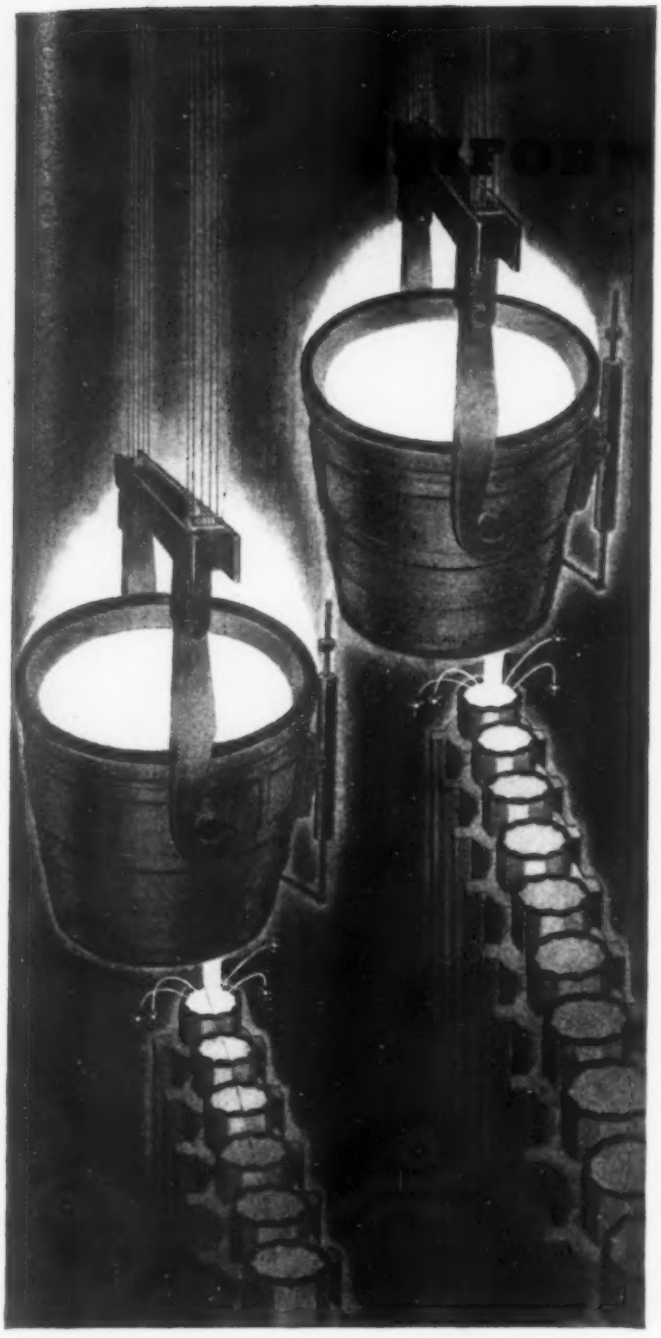
Company _____

Products Manufactured _____

Address _____

City and State _____

Postcard must be mailed prior to March 1, 1947—
Students should write direct to manufacturers.



FORGING QUALITY starts in the Timken Melt Shop

Forging improves steel quality, but it won't make good steel out of poor steel. *Forging quality is born in the melt shop.*

As this fact becomes better known, more and more steel users are placing Timken in the preferred position as a source for alloy forging steels.

Because the rigid system of quality control which governs melting in the Timken mills is excelled nowhere in the industry.

Because the personnel in no other melt shop has such specialized experience in producing alloy steels to close specifications.

Because research programs of The Timken Company have established countless new facts which have led to improved techniques in electric and open hearth furnace operation.

Advanced melting practice plus specialized processing techniques assure the uniform response to heat treatment so essential in producing good low cost forgings. Why not talk over your requirements with us, write Steel and Tube Division, The Timken Roller Bearing Company, Canton 6, Ohio.

SPECIALISTS in hot rolled and cold finished Alloy Steel Bars for forging and machining applications, as well as a complete range of Stainless, Graphitic and Standard Tool Steel analyses. Also Alloy and Stainless Steel Seamless Tubing for mechanical and pressure tube applications.

XPERIENCE AND RESEARCH

LABORATORY AND PLANTS of Industrial Steels are housed in this modern brick and glass building. Quarters are spacious, light, airy, and conducive to highest quality production. There is another large Industrial Steels warehouse not shown in this picture.

FURNACE ROOM of Industrial's modern Nitriding plant. Picture shows a corner of the furnace room with a retort being drawn from the pit furnace by the overhead monorail hoist.

NEWS ON NITRALLOY!

Boston now has a modern nitriding plant of large-scale production capacity

Industrial Steels, Inc., now licensed to do nitriding for users of Nitralloy, offers New England users of Nitralloy a modern chemical and metallurgical laboratory, a large battery of nitriding furnaces, and the experience of years in the surface-hardening of metals.

Nitralloy's two technical consultants in this area are immediately available for consultation on technical problems of Nitralloy processing and application. Call Industrial at any time to arrange appointment.

INDUSTRIAL STEELS, INC.

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Everything in Stainless Steel

Sheets • Bars • Tubing • Wire • Valves • Welding Electrodes • Pumps • Pipe Fittings • Hardware

CONTROL BOARD regulates flow of heat and nitriding agents to furnaces. Automatic instruments record temperature and gas analysis on each heat so that complete authenticated record is available to customer.

METALLOGRAPHIC LABORATORY is equipped for complete analysis of hardness, grain structure, and case depth. The most modern equipment for metallographic analysis is here housed in modern type building construction.

JMLee C1-DD2

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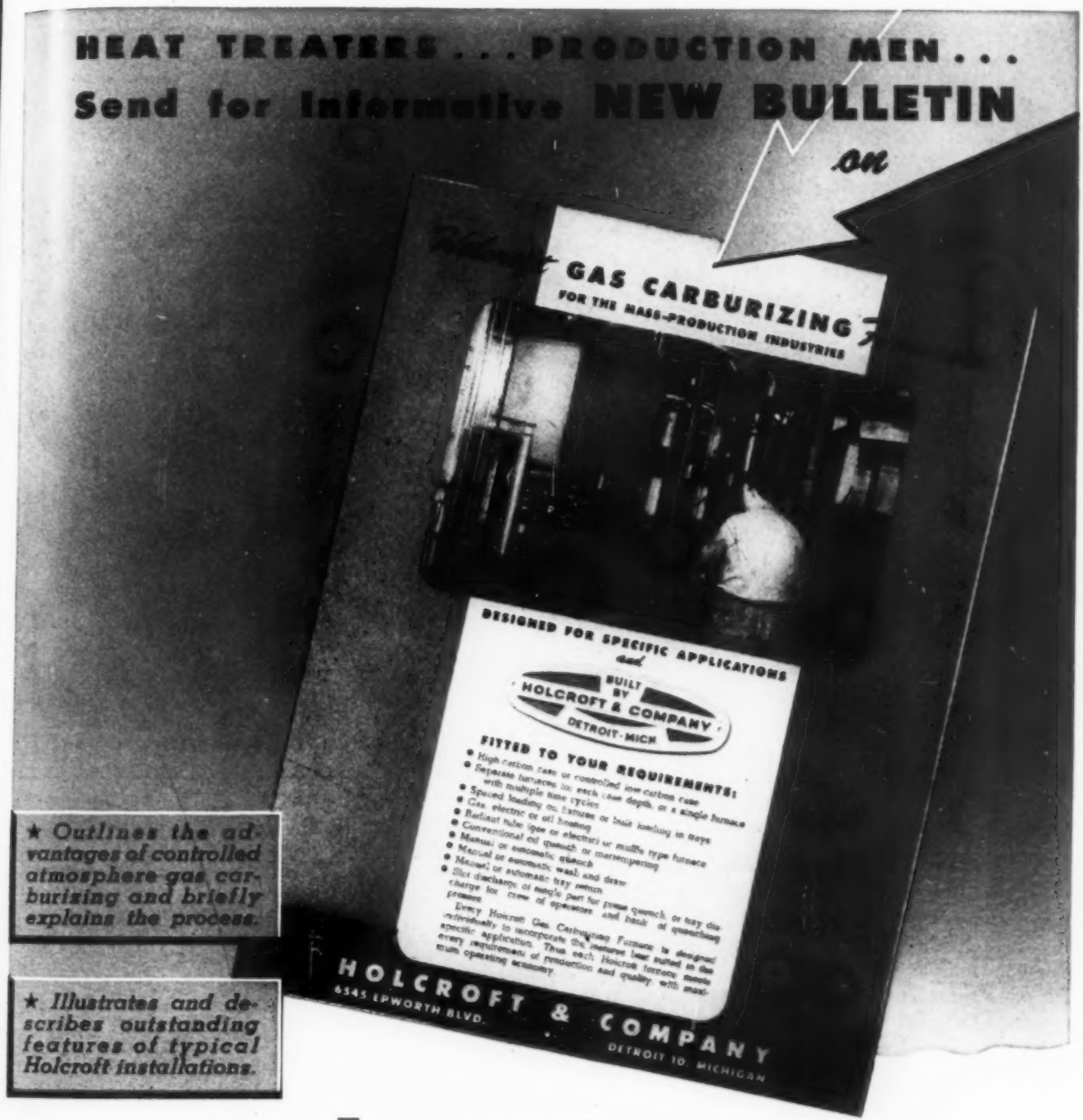
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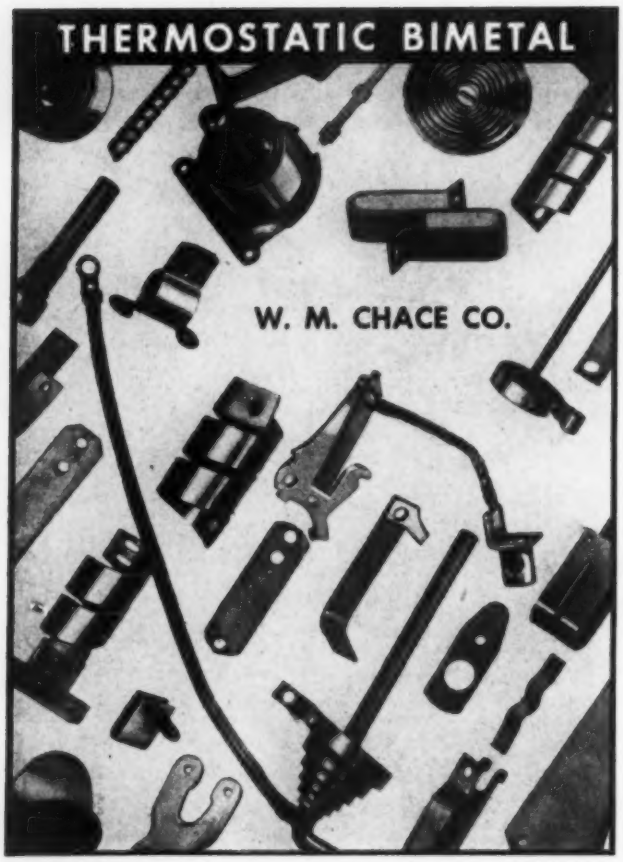

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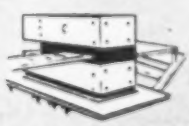

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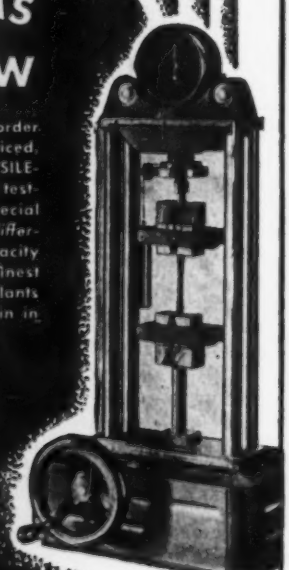

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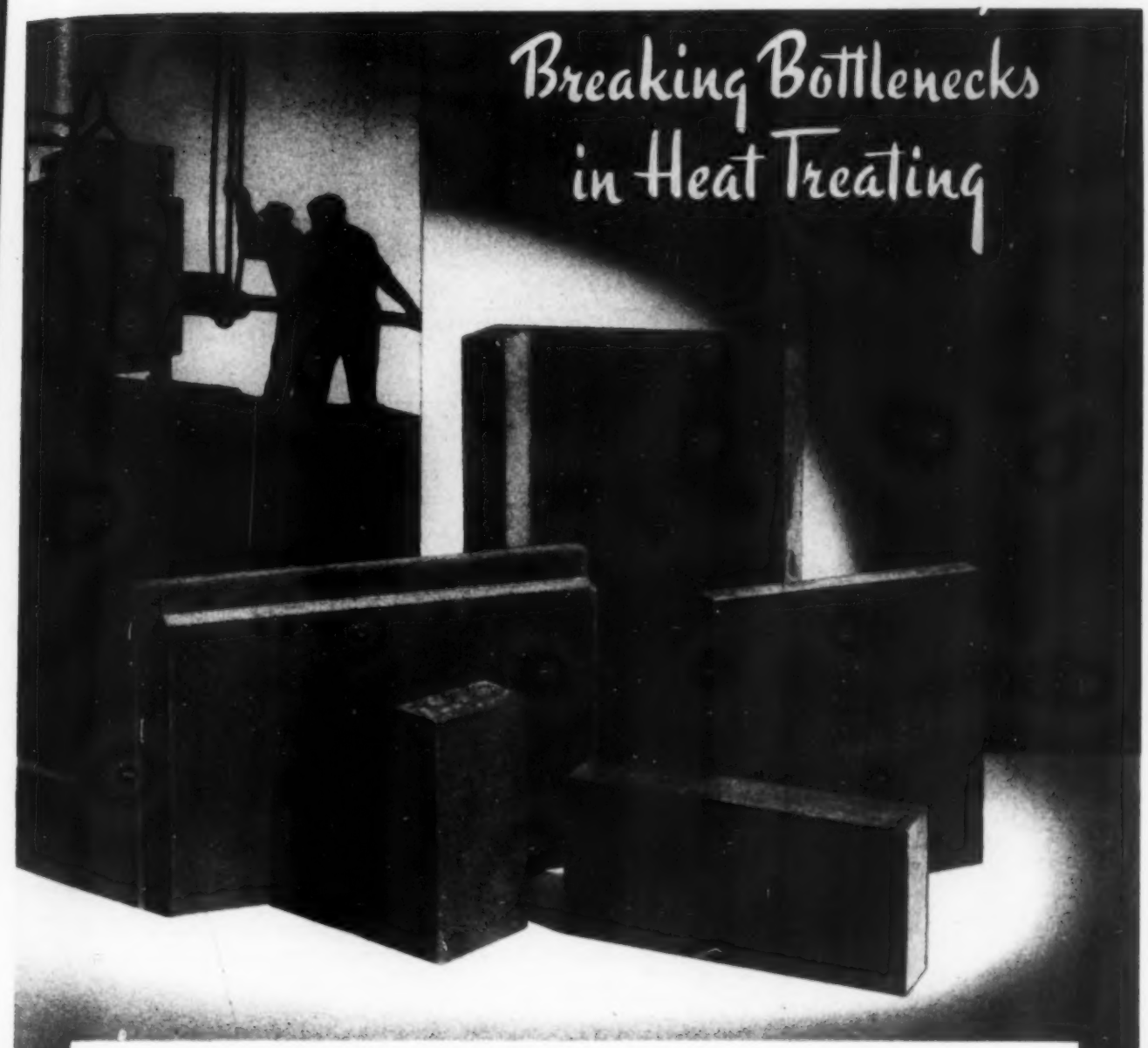

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PRODUCT	TYPICAL COMPOSITION	APPLICATIONS
ALSIFER	Aluminum .....20% Silicon .....40% Iron 40%	Used principally as a steel deoxidizer and for grain size control.
FERRO CHROMIUM High Carbon Grade	Chromium ....66-70% Carbon 4-6%	For wrought constructional steels and steel and iron castings.
Iron Foundry Grade	Chromium ....62-66% Carbon .....4-6% Silicon 6-9%	For alloyed cast irons. Readily soluble as a ladle addition at the lower temperatures of cast iron.
Low Carbon Grades	Chromium ....67-72% Carbon ...06%, .10%, .15%, .20%, .50%, 1.00% and 2.00% max.	For low carbon chromium steels, especially those with high chromium content, such as stainless and heat-resistant types.
FERRO SILICON 25-30% Grade	Silicon 25-30%	Deoxidizer for open hearth steels; also for high silicon, corrosion-resistant iron castings.
50% Grade	Silicon 47-52%	Used as a deoxidizer and for the addition of silicon to high silicon steels, for springs, electrical sheets, etc. Pulverized form used as ladle addition to cast irons for silicon content and graphitization control.
75% Grade	Silicon 74-79%	For high content silicon steels, such as spring steels, sheets and forgings of high magnetic qualities for electrical apparatus.
High Silicon Grades		
80-85%	Silicon 80-84.9%	For high content silicon steels where small ladle additions are used for required silicon content. Also for manufacture of hydrogen by reaction with caustic soda and production of magnesium by the Pidgeon process.
85-90%	Silicon 85-89.9%	
90-95%	Silicon 90-95%	
FERRO TITANIUM High Carbon Grade	Titanium .....15-18% Carbon 6-8%	Final ladle addition to control "rimming" action and to clean effervescing steel. Final deoxidizer and scavenger for steel castings and fully killed ingot steels.
Medium Carbon Grade	Titanium ....17-21% Carbon 3-4.50%	Often preferred to the High Carbon Grade as a final ladle addition to very low carbon rimming or effervescing steels.
Low Carbon Grades 20-25% Ti Grade	Titanium ....20-25% Carbon ...max. 0.10% Silicon .....max. 4% Aluminum max. 3.50%	Carbide stabilizer in high chromium corrosion resistant steels of extremely low aluminum content. Deoxidizer for some casting and forging steels.
40% Ti Grade	Titanium .....38-43% Carbon ...max. 0.10% Silicon .....max. 4% Aluminum ...max. 8%	Carbide stabilizer in high chromium corrosion-resistant steels, where smaller ladle additions are desired and extremely low aluminum content is not essential.
VANADIUM METAL 90% Grade	Vanadium ....91.15% Aluminum .....3.87% Silicon .....0.50% Carbon 0.17%	For special iron-free (non-ferrous) or low iron alloys or low impurity ferrous alloys.
95% Grade	Vanadium ....95.18% Aluminum .....2.00% Silicon .....0.27% Carbon 0.40%	Principally for research on the properties of pure alloys.

PRODUCT	TYPICAL COMPOSITION	APPLICATIONS
FERRO VANADIUM Grade "A" (Open Hearth)	Vanadium ....35-40% Silicon .....max. 12% Carbon ...max. 3.50%	For low percentage vanadium content of rolled, forged or cast constructional steels. Also used in vanadium cast irons.
Grade "B" (Crucible)	Vanadium ....35-45% Silicon ...max. 3.50% Carbon ...max. 0.50%	For tool steels and special steels containing high percentages of vanadium, in which required limits for carbon and silicon are narrow.
Grade "C" (Primos)	Vanadium ....35-45% Silicon ...max. 1.25% Carbon ...max. 0.20%	For tool steels and special steels requiring high percentages of vanadium and exceptionally low carbon and silicon content.
Special Grades	Vanadium ....50-55% 60-65% 70-80% Silicon .....Low Carbon .....Low	For special applications and uses requiring large vanadium additions.
VANADIUM PENTOXIDE Technical Grade Fused Form	V_2O_5 .....90%	A source of vanadium in basic electric furnace steels. A base for numerous chemical compounds.
Technical Grade Air Dried Form	V_2O_5 .....83-85%	A base for preparation of numerous chemical compounds, such as catalysts, etc.
GRAINAL ALLOYS Vanadium Grainal No. 1	Vanadium ....25.00% Aluminum ....10.00% Titanium .....15.00% Boron 0.20%	Practical and economical intensifiers for controlling and increasing the capacity of steels to harden, and for improving other important engineering and physical properties.
Vanadium Grainal No. 6	Vanadium ....13.00% Aluminum ....12.00% Titanium .....20.00% Boron 0.20%	See above.
Grainal No. 79	Aluminum ....13.00% Titanium .....20.00% Zirconium .....4.00% Manganese ....8.00% Boron .....0.50% Silicon 5.00%	See above.
GRAPHIDOX No. 4	Silicon .....42-46% Titanium .....9-11% Calcium 5-7%	New alloy for the graphitization of iron; ladle treatment insures iron with normal graphite, free from dendritic structure; reduces chill; efficient inoculant in the production of high strength irons.
V-FOUNDRY ALLOYS V-5 Grade	Chromium ....38-42% Silicon .....17-19% Manganese 8-11%	Used in cast irons as a ladle addition. Reduces chill, promotes uniformity of structure, increases strength and hardness.
V-7 Grade	Chromium ....28-32% Silicon .....15-21% Manganese ...14-16%	See above.
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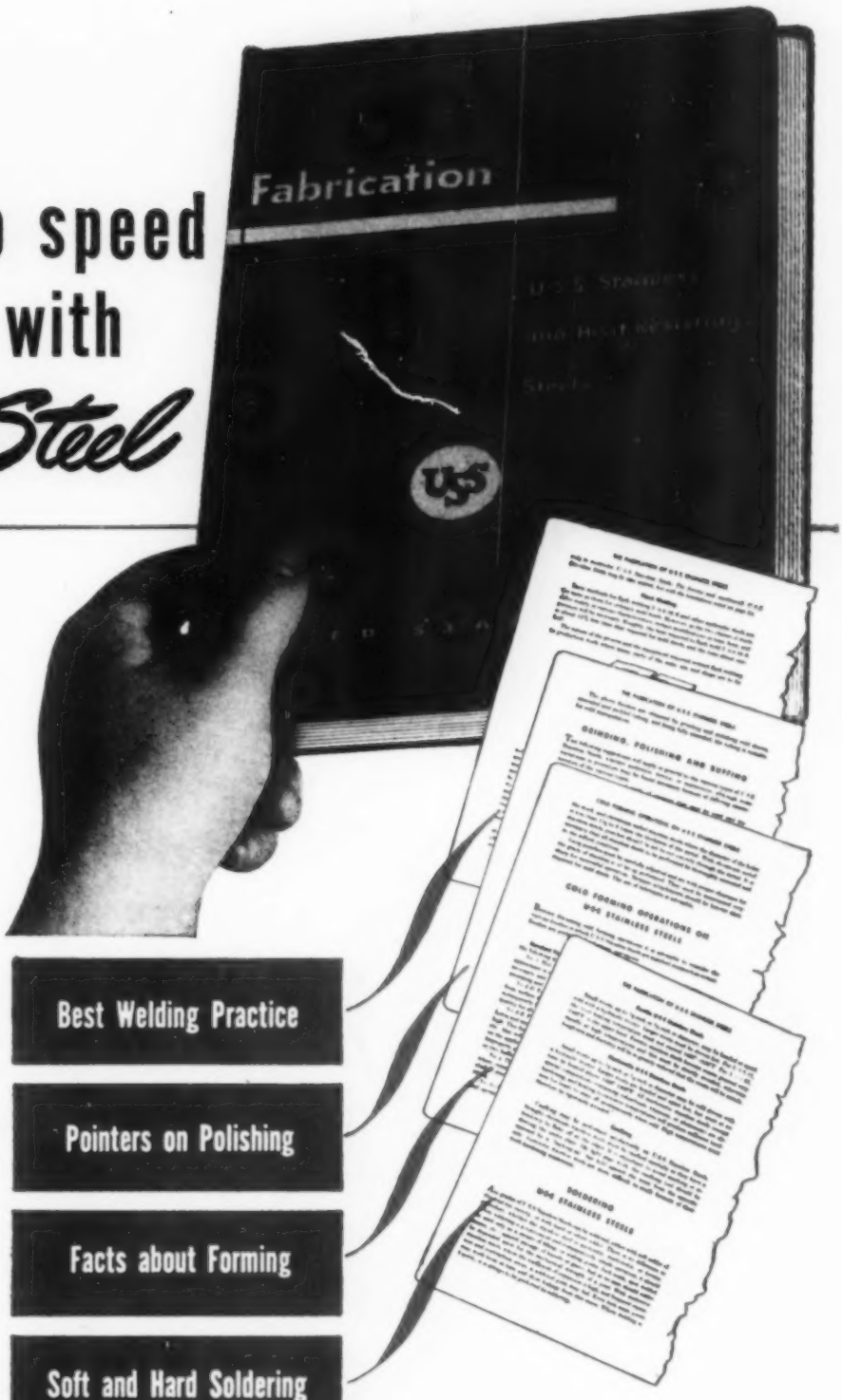

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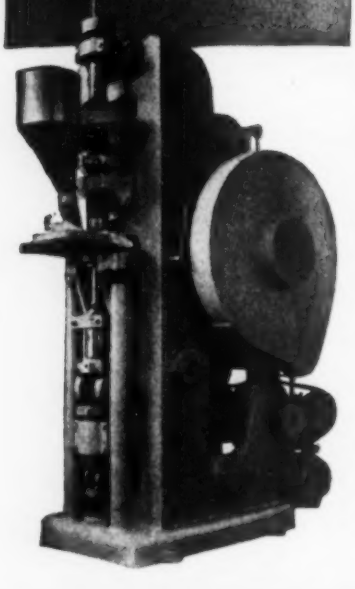
OF POWDER METALLURGY . . . FORMED ON STOKES PRESSES



The first porous bearings commercially produced were made on Stokes Tabletting Presses . . . and today it is a fact that more than 9 out of 10 automatically-made porous bearings are formed on Stokes machines.

Powder metallurgy is revolutionizing the manufacture of many parts because of lower costs and high-speed production. Thousands of manhours are saved. Parts are formed in seconds instead of being machined in hours. In many cases, parts that could be produced by no other method are a simple operation with powder metallurgy on Stokes Presses.

Products are dense if you want density . . . porous if you want porosity, for with Stokes Presses these characteristics are easily controlled. Alnico magnets, motor brushes, contact points, cemented carbide tool bits, ordnance components, iron gears . . . are just a few products being made successfully by unskilled labor on Stokes Automatic Tabletting Presses.

Stokes pioneered this type of equipment more than 25 years ago. New and improved models, of greater capacity and wider application, are being developed constantly.

Our engineering department invites your consultation. Send for 48-page illustrated catalog.

F. J. STOKES MACHINE COMPANY • 6006 Tabor Road, Phila. 20, Pa.

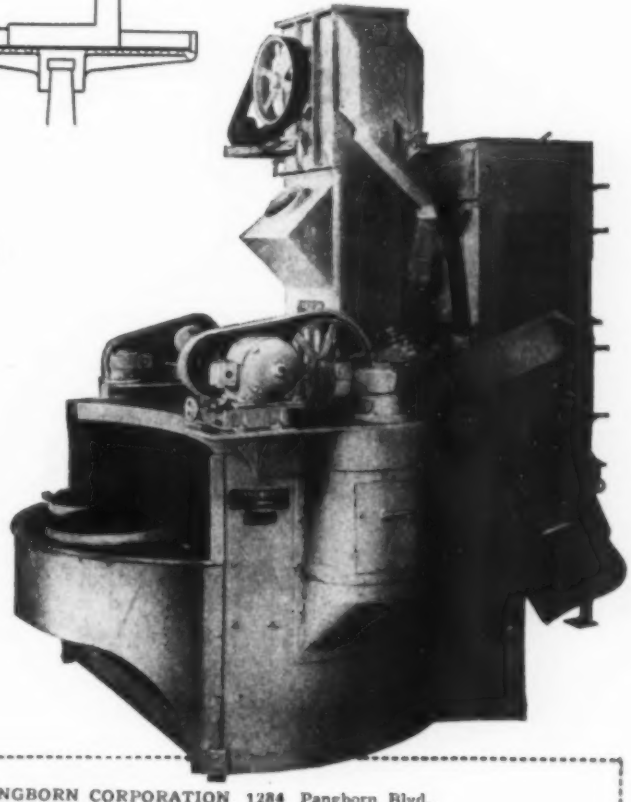
F.J.Stokes AUTOMATIC TABLETTING EQUIPMENT FJS Est 1895

BLAST CLEANING BOTH VERTICAL AND HORIZONTAL SURFACES *at One Time*

No other airless blast machine has this cost-saving feature

Thorough and uniform cleaning of vertical and horizontal surfaces with one pass through the machine—eliminating the necessity, in many cases, of turning the work for second and third passes . . . has revolutionized the blast cleaning of large or small castings and other metal parts on table-type machines.

Pangborn's ROTOBLAST* Table directs the blast stream onto the work at a 45° angle. Thus a great variety of shapes can be handled on this table with complete assurance that all planes will receive equal cleaning—no possibility of over-cleaning some planes.



And These Other PANGBORN FEATURES Save You More Time and Money

Variable table speed. Can be suited to the work—higher speeds (and higher production) for pieces easy to clean.

Large work openings. High work pieces easily handled.

Rim drive. Driving the table from the rim (instead of from center spindle) gives smoother motion and facilitates inspection of driving unit.

No clogging. The abrasive sweeps are rotated independently of the table; regardless of amount of abrasive thrown, the sweeps handle it without clogging.

Surface peening. Uniform abrasive impact over every point of the work table (due to 45° wheel) and variable table speed make this unit ideal for surface peening as well as blast cleaning.

Send coupon now for Bulletin 211A on ROTOBLAST Tables. And for any type of blast cleaning equipment—airless or compressed air—"Come to Pangborn", *world's largest manufacturer of blast cleaning and dust control equipment.*

*Trademark of the Pangborn Corporation

Pangborn

PANGBORN CORPORATION, HAGERSTOWN, MARYLAND

PANGBORN CORPORATION, 1284 Pangborn Blvd., Hagerstown, Maryland

Gentlemen: Please send me free Bulletin 211A on ROTOBLAST Tables.

Check also for information on: ROTOBLAST Rocker Barrels ☐

ROTOBLAST Special Machines ☐ Air Blast Rooms ☐

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THE NEW G-E GAS-

Offers You...

These FIVE Important Advantages:

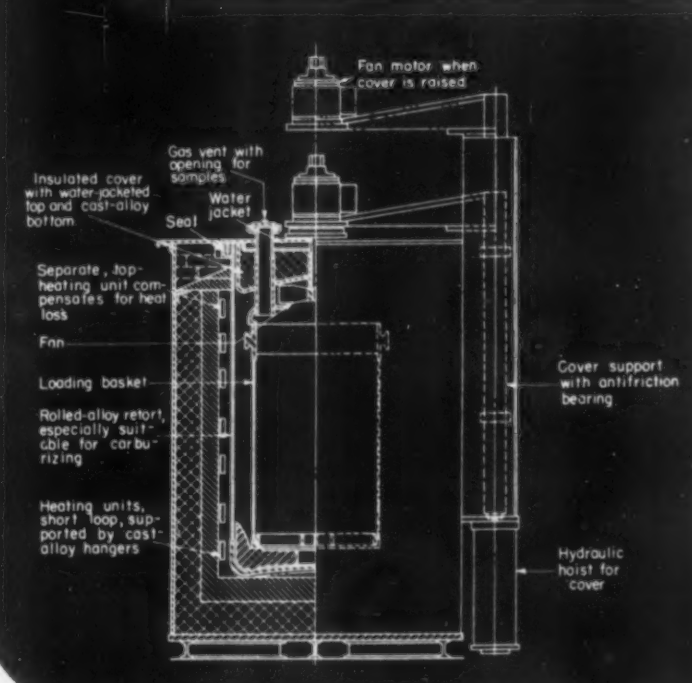
1. Uniform, Accurately Controlled Carburizing—With exact control of temperature, time at temperature, and gas distribution, the new, electrically heated G-E gas-carburizing furnace assures a uniform, high-quality output of carburized steel.

2. Short Carburizing Cycle—Accelerated heating by means of a high-powered furnace, and uniform heat distribution by a circulating fan, appreciably shorten the carburizing cycle.

3. Low Operating and Maintenance Costs—Using an inexpensive carburizing gas, having a short heating cycle, and requiring a minimum of material-handling operations—the new gas-carburizer is economical to operate. With a sturdy construction and a convenient arrangement of components, furnace maintenance is reduced and simplified.

4. Simple, Accessible Controls are conveniently provided on a single instrument panel.

5. Improved Working Conditions—With the elimination of solid carburizing compounds, working conditions are clean, and the general appearance of the heat-treating room is improved.

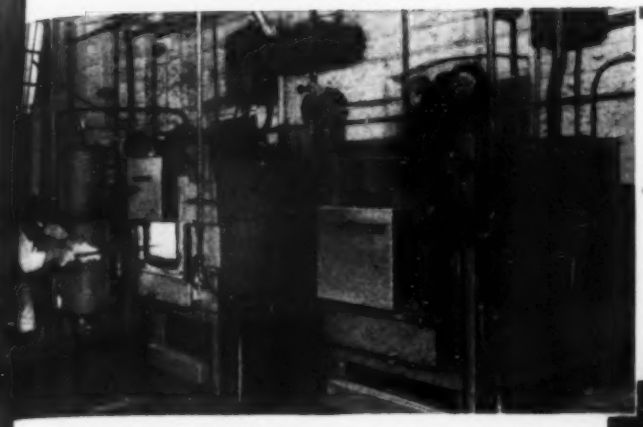

Fan motor when cover is raised
Gas vent with opening for samples
Insulated cover with water-jacketed top and cast-alloy bottom
Water jacket
Seal
Separate, top-heating unit compensates for heat loss
Fan
Loading basket
Rolled-alloy retort, especially suitable for carburizing
Heating units, short loop, supported by cast-alloy hangers
Cover support with antifriction bearing
Hydraulic hoist for cover

. . . And These Plus-dividends of Leadership:

- **Performance-proved Construction**
- **Technical Assistance**
- **Nationwide Field Service**

The new, standard gas-carburizing furnace, like all other G-E electric furnaces, assures you of performance-proved construction, based on steadily improved lines over almost a half-century of electric furnace research, design, and manufacture. To assist you in improving your product, experienced Heating Specialists are ready to help you to select your equipment and to recommend new, efficient techniques. And, in major cities throughout the country, an expert field organization is maintained to speed installations, solve operating problems, and to be readily available for servicing equipment.

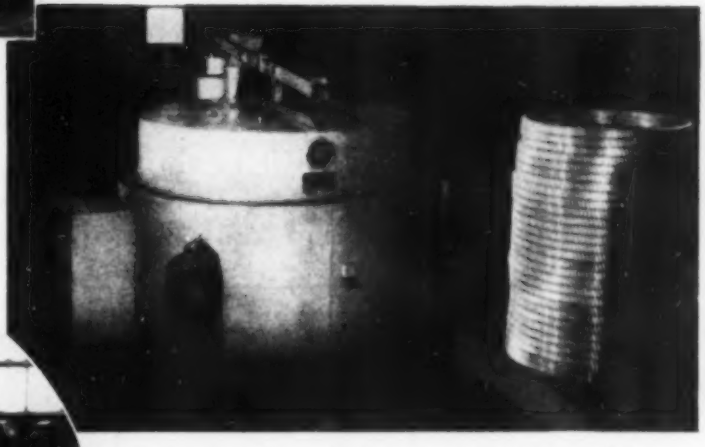
CARBURIZING FURNACE



You reap the benefits of G-E "know-how" on these heating equipments, too . . .

In addition to gas-carburizing furnaces, G.E. builds specially designed and standard furnaces for virtually every type of heat-treating process. Here are a few of the standard models:

Types "T" and "TG" high-temperature box furnaces, with protective atmosphere equipment, are used primarily for heat-treating high-speed steel without decarburization. With type "T" operating at 2000 F maximum, and type "TG" operating at 2500 F, these furnaces can also be used for miscellaneous high-temperature heating applications. Where decarburization and scaling are not factors, they may be used without atmosphere.



Pit furnace, with protective atmosphere, is used for heat-treating large gears, and for treating tubes and shafts which require suspension in the furnace to prevent warpage. Maximum operating temperature: 1850 F.

Air-draw box furnace—for drawing or tempering tools, dies, and other steel parts requiring accurate drawing temperatures up to 750 F. Standard models are also available up to 1250 F maximum.

For more detailed information on these furnaces, send us the coupon below. We will be glad to furnish you with *free*, descriptive bulletins.

In addition to furnaces, General Electric has also had wide experience in the development and construction of electronic induction, and dielectric heaters, and small heating devices, for a variety of applications. Our Heating Specialists and Application Engineers are prepared to recommend the electric heating equipment most suitable for your process. Call or write the nearest G-E Office.

General Electric Company
Apparatus Department, Sect. H675-140
Schenectady 5, N. Y.

Please send me bulletin GEA-3523B, "Gas-carburizing Electric Furnaces," and also the following (please check): ☐ GEA-3596A, "Type T Box Furnaces;" ☐ GEA-4065A, "Type TG Box Furnaces;" ☐ GEA-785C, "Air-draw Box Furnace;" ☐ GEA-4070, "Pit Furnaces."

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Columbia TOOL STEEL

COLUMBIA SPECIAL
Highest Grade Water Hardening Tool Steel
Best for Carbon Steel Dies and Cutters. Unexcelled for cutting and forming plastics, fibers, paper, and non-ferrous metals.
It pays to use Good Tool Steel

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ARTHUR T. CLEARAGE, PRESIDENT

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NEW TEMCO MODEL C E A

ELECTRIC FURNACE

The new MODEL C E A has been designed to give superior performance, with ease and economy of operation, at a low initial cost. It will stand hard use and is an ideal furnace for general laboratory purposes, heat-treating and small unit production.

SPECIFICATIONS

Temperature Control — Any temperature from 500° F. to 2000° F. can be selected and automatically maintained with TEMCO variable temperature control.

Pyrometer — Indicating type calibrated in both Fahrenheit and Centigrade scales.

Dimensions—Inside 4¾" wide, 4¼" high, 6" deep. Outside 12" wide, 15½" high, 14½" deep.

Prices Model CEA Complete
For 115 V.—A.C. only....$80.00
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For 230 V.—A.C. only.... 85.00

- Heats up to 1500° F. in 30 minutes.
- Can be operated continuously up to 2000° F.
- Embedded heating element protected against damage and chemical deterioration. Muffle core easily replaceable.
- Heating element, special high temperature alloy, completely surrounds heating chamber assuring the most uniform distribution of heat.
- Insulated with highly efficient, light-weight materials cast permanently into furnace body.

Other sizes available

See your supply house or write for literature

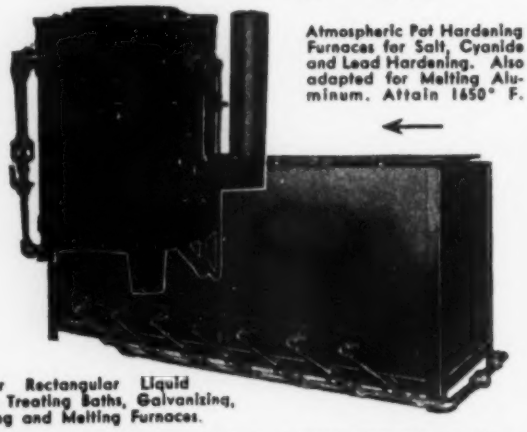
THERMO ELECTRIC MFG. CO. 487 W. Locust St., Dubuque, Ia.

✓ PLAN TO INSTALL

BUZZER
Reg. U.S. Pat. Off.

INDUSTRIAL *Gas* EQUIPMENT

NO BLOWER or POWER NECESSARY
. . . just connect to gas supply



Atmospheric Pot Hardening Furnaces for Salt, Cyanide and Lead Hardening. Also adapted for Melting Aluminum. Attain 1650° F.

Buzzer Rectangular Liquid Heat Treating Baths, Galvanizing, Tinning and Melting Furnaces.

Send for the complete "BUZZER" Catalog

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Many Outstanding Installations

CARL-MAYER CAR TYPE ANNEALING FURNACE, direct gas fired, as installed for the Cleveland Chain Company.

• **FOR MORE THAN 25 YEARS** Carl-Mayer furnace and oven performance has been on the preferred list of America's leading concerns.

Why not get the benefit of our engineering achievements on *your* next installation?

Write for Bulletin!

The CARL-MAYER Corp.

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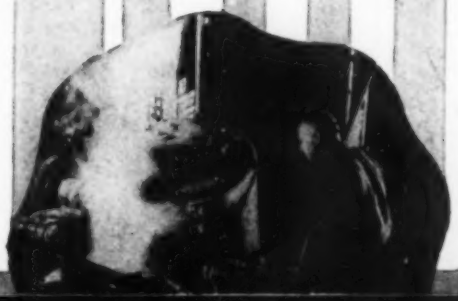
SEYMOUR



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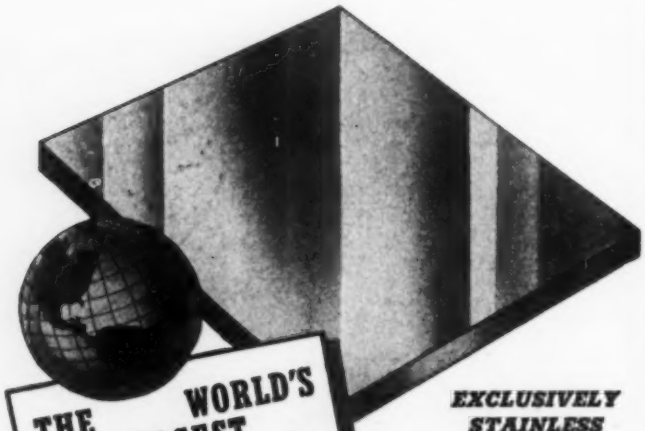
THE IDEAL BASE FOR PLATED WARE

The base, or "body," of much of the silver, nickel and chromium plated ware made in this country is Seymour Nickel Silver—an alloy of copper, nickel and zinc. Tarnish-resistant, silvery-white in color—when it is eventually exposed by wear, there is no unsightly contrast. It is capable of any degree of ductility, from dead soft to spring temper. This makes it the perfect alloy for spinning, drawing and stamping. When leaded, it has excellent workability and causes no undue wear on tools. If your present metal or alloy is not all that it should be, why not change to Seymour Nickel Silver?

THE SEYMOUR MANUFACTURING CO., SEYMOUR, CONN.

NONFERROUS ALLOYS SINCE 1878



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EXCLUSIVELY STAINLESS

PLATES
FORGINGS
BARS
SHEETS
AND
BILLETS

The production of these large plates falls within the classification of routine production at G. O. Carlson, Inc. We are particularly well equipped both in engineering experience and facilities to produce almost any quantity of stainless steel in the forms listed at right. Call us for quality service on your next job.

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Dependability
Engineering
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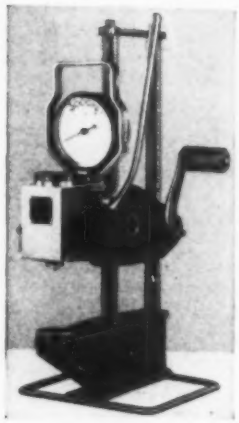
KING PORTABLE BRINELL

HARDNESS TESTER

How many times have you carried heavy work to the Brinell Tester? Too often, you'll say.

Here is a 26-lb. portable tester you can easily take to the work and save time and trouble by doing your Brinell work on the job. The King Portable Brinell puts an actual load of 3000kg on a 10mm ball. It can be used in any position.

The test head is removable for testing larger pieces beyond the capacity of the standard base.



Throat—4" deep. Gap—10" high. Weight—26 lbs.

Let us show you how we can lighten your Brinell testing.

ANDREW KING
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Char CARBURIZERS

Available
in Standard
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Char Carburizers are screened to standard size — passing through a 3/8" screen and retained on an eight mesh screen. Special sizes can be furnished to meet your requirements. Packed in 100 lb. bags for convenience in handling.

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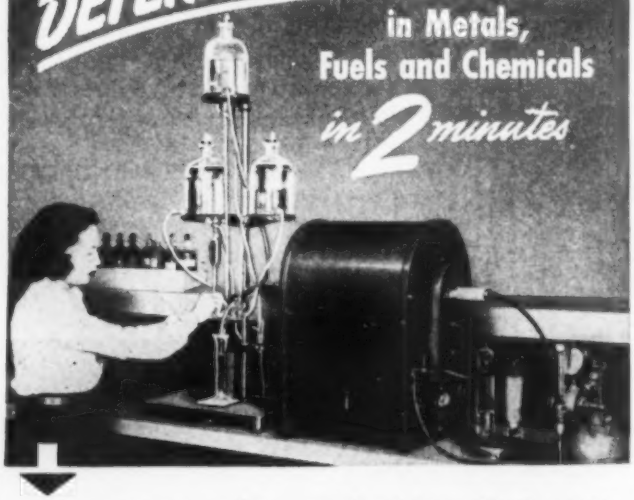
DETERMINES SULFUR

in Metals, Fuels and Chemicals *in 2 minutes*



- Accuracy equal to gravimetric method meets standards of procedure recommended to ASTM.
- Costs less than comparable equipment.
- Adaptable to both alkaline and iodate methods.
- Requires less skill in handling than other equipment.
- Pipettes and burette designed for automatic zeroing.

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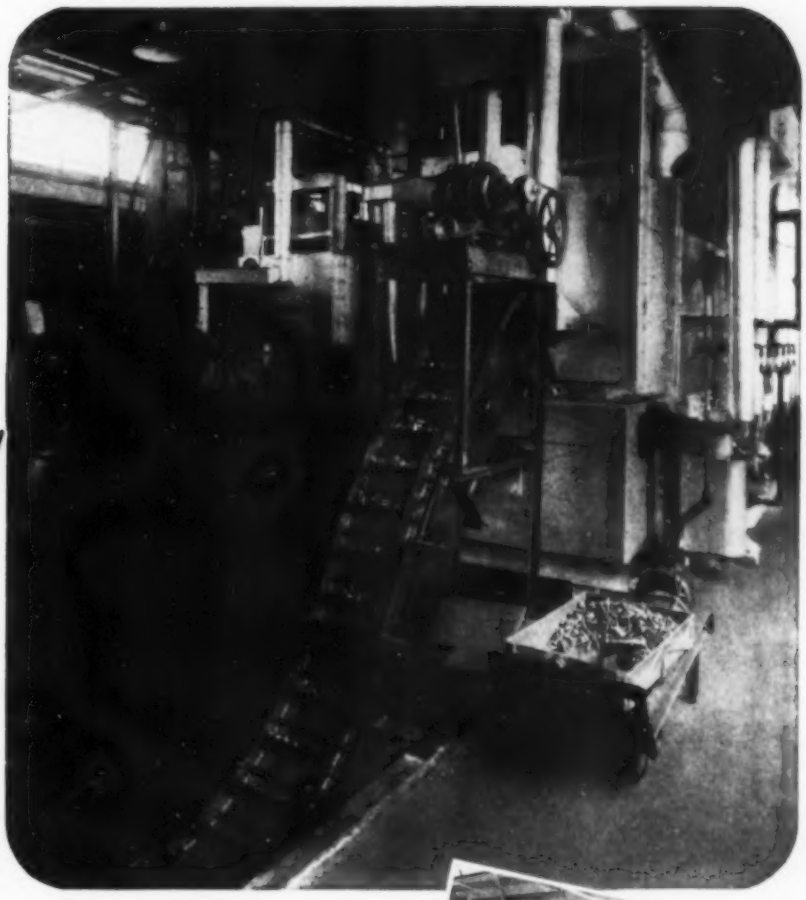

SCALE FREE · LOW COST · CONTINUOUS · hardening of small parts

EF CONTINUOUS CHAIN BELT CONVEYOR TYPE FURNACES are furnished in gas fired, oil fired and electric designs, in 11 standard sizes ranging from 175 lbs. to 2000 lbs. capacity per hour. The material to be processed is loaded onto the cast link heat resisting conveyor belt, either manually or from a conveyor, is carried into the furnace automatically, heated uniformly and accurately to the desired temperature, quenched and discharged. The furnaces are readily adapted to use with special protective atmospheres for heat treating and hardening without scaling or decarburization.

Performance records of hundreds of installations prove that these furnaces are unsurpassed for the efficient economical heat treatment of a wide range of small and medium size parts ranging from washer and springs to tractor treads and engine parts. But send for our 12 page Bulletin No. R-1—"Chain Belt Conveyor Furnaces"—it gives full details—and let EF engineers, with their long and successful experience in building production furnaces for heat treating all types of products, work with you on your next heat treating job!

THE ELECTRIC FURNACE CO.

GAS FIRED, OIL FIRED AND ELECTRIC FURNACES FOR ANY PROCESS, PRODUCT OR PRODUCTION

Salem-Ohio

PLOWSHARES coming up

As we approach the end of 1946 we pause to be grateful for the return of industry to a competitive peacetime economy . . .

And to you, our friends in industry, we say a very sincere thank you for your co-operation during the year.

We wish you all the traditional joy and peace of a very Happy Christmas . . . followed by a New Year made satisfying because of its accomplishments.

THE GATHMANN ENGINEERING COMPANY

Emil Gathmann, President

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